A FEEDBACK DYNAMICS MODEL OF THE DEVELOPMENT OF DEKALB COUNTY, GEORGIA

A Thesis

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A FEEDBACK DYNAMICS MODEL OF THE

DEVELOPMENT OF DEKALB COUNTY, GEORGIA

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SUMMARY

In the United States today, the problems associated with metropolitan areas are rapidly becoming a major concern of all levels of government. The concentration of so many of the nation's people in relatively small areas has resulted in overcrowding, inadequate housing, crime, slums, unemployment, inadequate transportation systems, and pollution. Much research has been devoted to understanding urban development processes so as to aid urban decision-makers in more effectively dealing with these problems.

This thesis presents a compouter model for DeKalb County, Georgia, which simulates the county's growth and development from 1960 to 2060. It is based on the basic concepts proposed in J. W. Forrester's Urban Dynamics' model. The main objective of the thesis is to understand why the problems mentioned in the preceding paragraph occur. The model of DeKalb County is intended to serve as the basis for development of a more comprehensive model of the county which can be used as both a planning aid and policy-evaluating tool. As such, this thesis focuses more on the explanation of the forces causing the county's development rather than on the prediction of the county's future.

The model shows that the county experiences a period of growth followed by a period of decline and another growth phase due to changes in its relative attractiveness over time. The changes in relative attractiveness are caused by conditions both internal and external to the county. The pattern of DeKalb County's development may be generalized

to imply a cycle of development for metropolitan areas. In addition, the model shows that a county government committed to deficit spending must also be committed to growth, for if the market value of land fails to increase rapidly enough due to decreased growth, a crisis situation develops.

It is felt that this thesis adds to the understanding of urban development processes. The model's behavior is accurate for the period 1960 to 1970. However, it may not be used as a general policy-evaluating tool due to deficiencies in its scope and its sensitivity to changes in certain parameters. The model can serve as the base for development of a more comprehensive model, and such expansion would be appropriate.

CHAPTER I

INTRODUCTION

Introductory Description of the Problem

In the United States today, the problems associated with metropolitan areas are rapidly becoming a major concern of all levels of government. The concentration of so many of the nation's people in relatively small areas has resulted in overcrowding, inadequate housing, crime, slums, unemployment, inadequate transportation systems, and pollution. In DeKalb County, Georgia, these problems are beginning to appear as a result of the rapid rate of growth the county has experienced in the past twenty years. The county government's debt has risen, it's tax base is unstable, and there is a fear that the county's quality of life is deteriorating. The government is beginning to respond to this fear, as evidenced by it's consideration of alternative growth-control plans.

Thesis Objective

Naturally the county's government is interested in solving the problems mentioned above. Solving these problems is obviously beyond the scope of this thesis. The objective of this thesis is to understand why the problems occur. Specificially, it is desired to know why population and industrial growth occurs, how they are related, how land use is affected by their growth, and how the governments' finances are impacted. A feedback dynamics model of DeKalb County simulating its development from 1960 to 2060 is designed to do this. This model is intended to serve as the basis for development of a comprehensive model of the county which can be used as both a planning aid and policy-evaluating tool. As such, this thesis focuses more on the explanation of the forces causing the county's development rather than on the prediction of the county's future.

Thesis Procedure and Methodology

The methodology of this thesis consists of six steps: problem identification, dynamic hypothesis development, model building, validation and hypothesis testing, and model improvement. The problem has been stated previously. Dynamic hypothesis development involves gathering data, characterizing the time histories of important variables, surveying the literature of prior work in the field, drawing conclusions from the time histories and the literature, and formulating the hypothesis from these conclusions. The model building draws upon the dynamic hypothesis, interviews with knowledgable officials in the county government, and additional data quantifying the various model parameters. As stated before, the model is a feedback dynamics model, and as such, is formulated in DYNAMO I simulation language. The output of the model is a computer simulation of the county's development from 1960 to 2060. The validation and hypothesis testing step consists of comparing the output with the actual time histories of important parameters from 1960 to 1970 and varying critical parameters to determine any logic inconsistencies in the dynamic hypothesis. Any inconsistencies found are corrected in the final step of model improvement. As stated earlier, it is beyond the scope of this thesis to consider the further steps of real system modification and control, measurement and evaluation of the modifications, and recycling of the methodology based on the evaluation.

Relevant Literature

The second step of the methodology involved surveying the literature of prior work in the field. The literature in the area of urban development is widely diverse and interdisciplinary. However, this section will cite those works which developed the basic concepts in the field, those which utilized these concepts in modeling urban areas and their development, and those upon which the model in this thesis is based.

Two significant trends in population migration served as starting points for researchers in the area of urban development. The first was the migration of people from rural areas to urban centers. In 1900, 32 percent of the country's population lived in 52 areas which would have been classified as Standard Metropolitan Statistical Areas. In 1970 over 68 percent of the country's population, which had increased 160 percent, resided in such areas. The second trend was that of population migration from the "central core" areas to the "suburbs" within metropolitan areas. In 1900 the population of the "central cores" of metropolitan areas was 62 percent of the total population of such areas, but in 1970 only 46 percent of the population lived in the "core" areas. The initial attempts of theorists to quantitatively explain the phenonenon of migration centered around H. C. Carey's gravity concept of human interaction.[3] This concept ". . . postulates that an attracting force of interaction between two areas of human activity is created by the population masses of the two areas, and a friction against interaction is caused by the intervening space over which the interaction must take place." This relationship was expressed mathematically in the following manner:

$$iM_j = \frac{f(P_i,P_j)}{f(D_{ij})}$$

where

iM_j = migration from source j to center of absorption i;

$f(P_i,P_j)$ = some function of the population of areas i and j, respectively,

and

D_{ij} = distance between center i and center j.

In the late 1920's E. C. Young[3] introduced a "force of attraction" term in his modification of the gravity concept of human interaction. This led to continued modification of the gravity concept by other researchers, but it eventually initiated research along a somewhat different line. This research employed linear regression and correlation analysis to determine variables significant in the migration trends mentioned previously. Early studies, such as T. R. Anderson's,[4] focused on only a few variables to explain intermetropolitan migration. Later studies included numerous variables. For example, J. D. Tarver[5] categorized 24 individual factors into three categories. However, the aim of all of this research was the determination of factors which were significant in the composition of the "force of attractiveness" factor in the gravity concept of human interaction as proposed by Young.

Model building incorporating the findings of the aforementioned studies naturally occurred, and in fact, spurred further research on migration trends. The models of interest are those which are dynamic in nature and have been used in actual planning endeavors. Specifically, the U.N.C. land use succession model of Chapin, Weiss, and Donnelly,[6] the EMPIRIC location model,[7] the POLIMETRIC migration model,[8] and a dynamic version of Lowry's Pittsburgh model[9] are cited. These models have two unifying characteristics; they all possess some type of "evaluation" or "attractiveness" function which allows discriminatory migration of classes of activities between sectors of the area under study, and they all base the total activities which can migrate in each time period on forecasts external to the area. It is noted that the "attractiveness" function is firmly grounded on the concepts introduced by the studies mentioned previously. Typically these models begin with a predetermined amount of activities (population, industrial firms, governmental units, etc.) which must migrate into and between sectors of the area in each time period. The manner in which these activities migrate depends on relative "attractiveness" scores between sectors. The "attractiveness" scores are predominantly combinations of factors which have been determined as significant by the studies mentioned earlier. Each sector has various constraints placed on the amount of activities it can sustain, and when these constraints are reached, no further migration is allowed into that sector. This procedure is followed during successive time periods. By analyzing the contents of each sector over the course of the simulation, an urban development pattern may be determined, both in a numerical and spatial sense, since the sectors are locatable on a map.

These models led to further research into the factors significant in migration. However, the focus of these studies[10,11,12,13] was on intrametropolitan migration rather than intermetropolitan migration. The most notable contribution of these was Simmon's formal statement of the concept of "place utility."[10] He defined "place utility" as " . . . a measure of attractiveness of an area, relative to alternative locations, as perceived by the individual decision maker."

J. W. Forrester based his Urban Dynamics[14] model on the concept of "relative attractiveness" which is distinctly similar to the concept of "place utility" mentioned above. He models a generalized urban area utilizing this concept, but the model is fundamentally different from the models described earlier. He rejects those models' contention that the changes occurring in an urban area are externally determined (i.e., by forecasts external to the area), but rather states that the condition of an urban area directly affects its future state. Forrester's model utilizes causal relationships between component parts of the metropolitan area to determine the model's structure. These parts consist of three classifications of people, housing, and industry (high, middle, and low class). The changes in these component parts over time are based in part on the "relative attractiveness" concept and are accomplished through feedback loops present in the system. There have been several models based on Forrester's, notably Hester's "ring-core" model[15] and the Lowell Dynamics Project.[16,17] Hester's model decomposes Forrester's into the subgrouping of "ring" and "core" for the classifications of population, housing, and industry. It focuses on job and land availability as prime determinants of population movement between the "ring" and "core." The Lowell Dynamics Project duplicates the Urban Dynamics'[14] model on a different scale and at present is primarily concerned with ascertaining the validity of Forrester's approach. It is noted that both Hester's model and the Lowell Project employ the same formulation and basic assumptions as Forrester's model.

The model to be presented in this thesis is somewhat patterned after Forrester's model. It is based on the concept of "relative attractiveness," which is the mechanism by which people and industrial firms migrate into and out of the urban area under study (DeKalb County). However, there are some notable differences in this model. First, this work is concerned with a portion of a metropolitan area rather than an entire metropolitan area. This necessitates a redefinition of the environment external to the study area and significantly affects the data requirements. Secondly, the model explicitly includes the government's financial structure. This directly states that the government's financial condition is part of the overall state of the county. Finally, provision is made for a dynamic rather than static environment. Flexibility is provided for testing assumptions about the environment in the future.

Results

The DeKalb County model shows that the county experiences a period of growth followed by a period of decline and another growth phase due to changes in its relative attractiveness over time. The changes in relative attractiveness are caused by conditions both internal and external to the county. The pattern of DeKalb County's development may be generalized to imply a cycle of development for metropolitan areas. In addition, the model shows that a county government committed to deficit spending must also be committed to growth, for if the market value of land fails to increase rapidly enough due to decreased growth, a crisis situation develops.

Conclusions and Limitations

It is felt that this thesis adds to existing knowledge of urban development processes. The model's behavior is accurate for the period 1960 to 1970. However, it may not be used as a general policy-evaluating tool due to deficiencies in its scope and its sensitivity to changes in certain parameters. The model can serve as the base for development of a more comprehensive model, and such expansion would be appropriate.

CHAPTER II

THE MODEL

Basic Concepts

As mentioned before, the model to be described in this chapter is formulated in DYNAMO I simulation language. A detailed description of the program equations is given in Appendix I and a complete listing of the program is contained in Appendix II. Data on which parameter values are based are given in Appendix III. This chapter will deal primarily with the basic structure of the model and its underlying concepts. It is assumed that the reader is familiar with the basic feedback dynamics' notions of accumulations, rates, and auxiliary variables as well as the general relationships between them.

In the modeling of any complex system, the distinction between the system and its environment must be made. Forrester states "In feedback dynamics methodology this distinction is determined by the interactions which create the dynamic behavior of interest. The model is structured such that the characteristic system modes of behavior are generated by interactions between system and not environmental variables."[14] In this particular model the system is defined as DeKalb County, Georgia, and the environment is the Atlanta metropolitan area. The structure of the system will be discussed, but first the implications of the choice of the environment will be presented.

The choice of the environment as the Atlanta metropolitan area necessarily affects the data requirements of the model. In addition, the assumptions concerning the migration of people and industrial firms are modified by this choice. In Urban Dynamics,[14] after which this model is somewhat patterned, the type of migration processes being dealt with are rural-urban and intermetropolitan. By selecting the Atlanta metropolitan area as the environment, the focus is changed to intrametropolitan migration. It is assumed that people and industrial firms first select Atlanta as a general location site and then decide on their specific residence once their decision to move to Atlanta is made. This assumption effectively reduces pertinent migration flows to intrametropolitan ones of large magnitude, and has impact on perception times and the component parts of the county's "relative attractiveness."

The previous paragraph suggests that migration processes are an important feature of the model. This is true, for it is the migration of people and industrial firms into and out of the county, in response to its present condition which determine its future condition. Underlying the migration of people and industrial firms is the concept of "relative attractiveness." This concept is present in one form or another in practically every model designed to explain or predict urban development.[6,7,8,9,14,15,16] The concept of "relative attractiveness" states that it is the relative, not absolute, attractiveness of an area which determines the rate and direction of migration flow. As Forrester[14] explains,

> Using the Environment as a Reference Point means that conditions within the urban model are being generated relative to the environment. The model shows how the area becomes more or less attractive than the surrounding environment and thereby causes the movement of industry and population to and from the area.

Only differences in attractiveness between the area and environment are significant.

In this model the environment is characterized by four variables which change over time. This is a departure from Urban Dynamics,[14] which holds the environment constant, for it is felt that the absolute magnitudes of these environmental variables are as important to the urban decision-maker as their relative magnitudes to their county counterparts. The "relative attractiveness" of the county at any point in time is determined by a combination of the influences of the ratios of county characteristic variables to their environmental analogs. The variables selected as components of the county's "relative attractiveness" were determined by linear regression techniques, previous studies,[11,12,13] and interviews. The values of the county variables are generated by interactions within the system, while the environmental variables are given externally. The influences which the ratios of these variables have on the county's "relative attractiveness" are quantitatively described by non-linear table look-up ("TABHL") functions.

Model Structure

The structure of the model is determined by the causal relationships existing between component parts of the county. Feedback loops are used to depict these relationships and are crucial in determining the nature of the behavior of the model. The model itself is composed of four interacting sectors: Government, population, industrial, and land (see Figure 1). This delineation varies from that presented in Urban Dynamics entirely. The inclusion of the government is to allow analysis of the government's condition as part of the overall state of

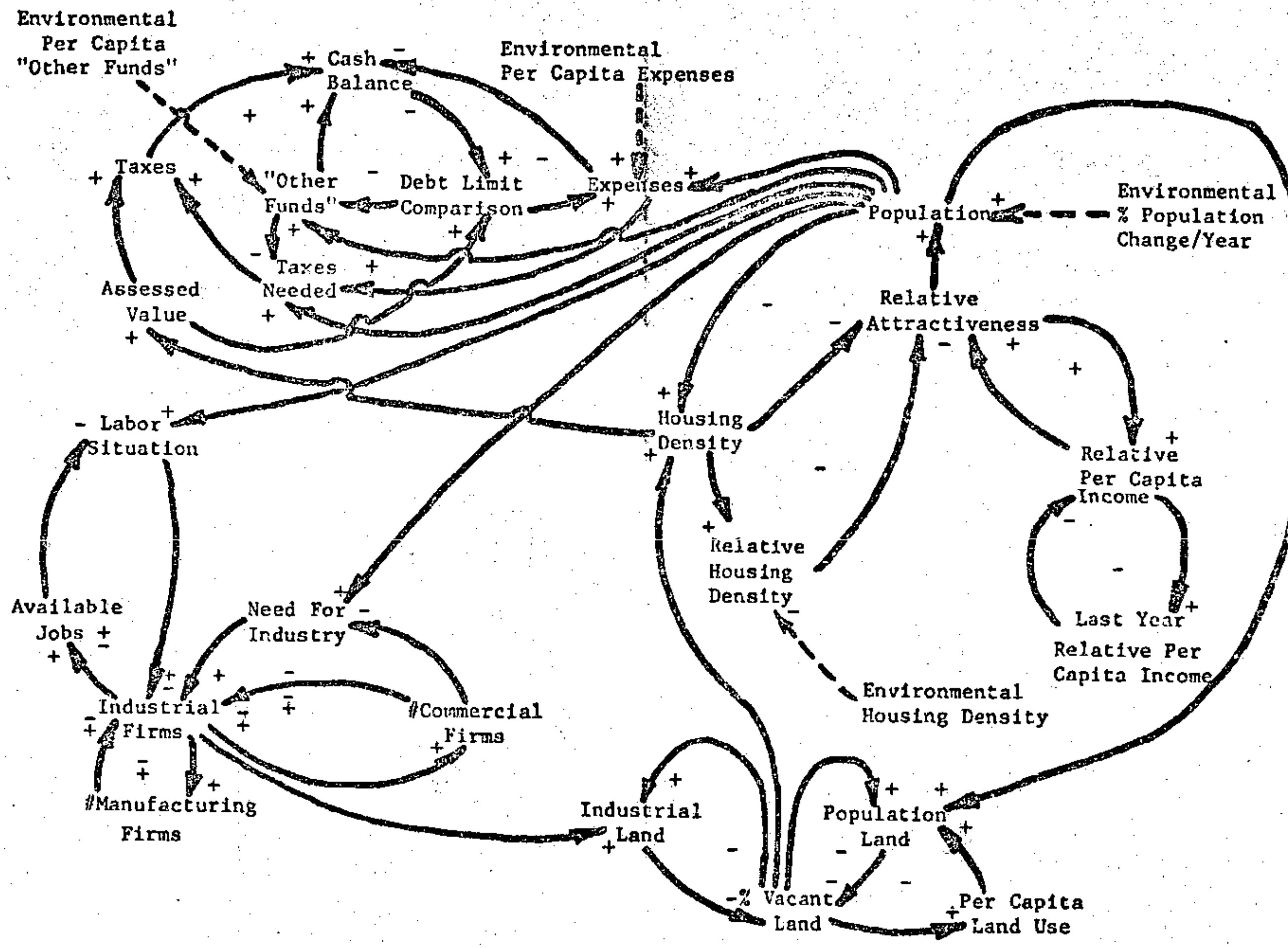


Figure 1. Influence Diagram--DeKalb County, Georgia, Model.

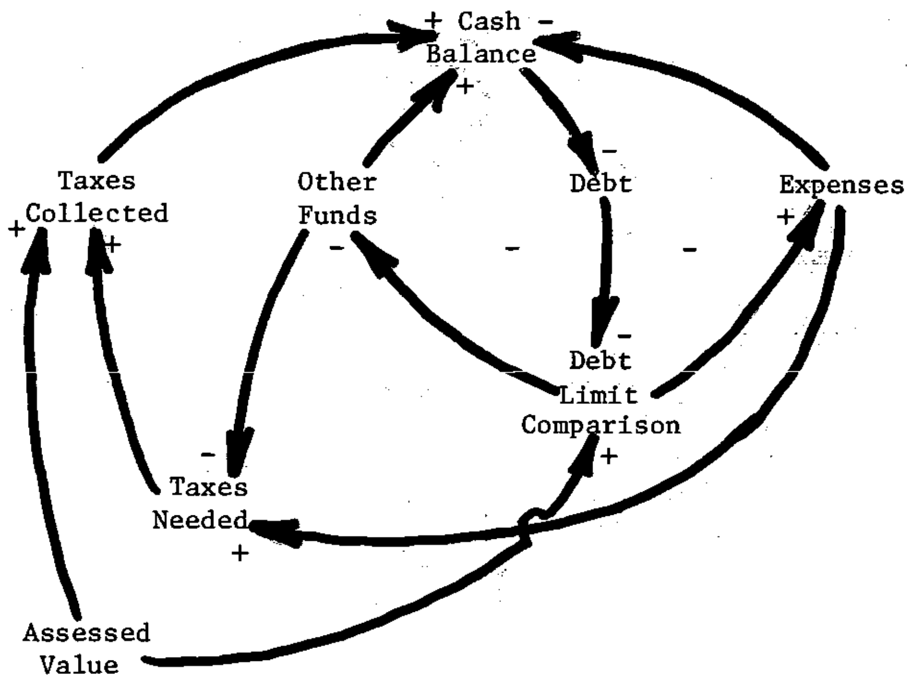
the county. The explicit exclusion of a housing sector is necessary due to the level of aggregation of the model. Housing is represented as part of the population sector, and its essential influences are included. Diagrams of each of the sector's internal feedback loops will be presented, but the reader is urged to refer to Figure 1 to maintain his overall perspective of inter-sector relationships. Tables listing the constants contained in each will accompany their respective sector description.

Government Sector

The Government Sector represents the financial structure of the government and is an aggregation of both the County Government and the County School Board. Both expenses and revenues are considered, the former being expressed on a per capita basis, the latter being a combination of taxes and "other funds" (service fees, license fees, and governmental transfers). The comparison by county officials of the county's debt with respect to its constitutionally-imposed limit directly influences both expenses and revenues. Figure 2 shows the influence diagram of the internal loops of the Government Sector and lists the influences of variables external to the sector on variables within the sector. Tables 1 and 2 list the constants and "TABHL" function values contained in the sector, respectively, All dollar amounts in this simulation are based on the 1960 dollar value.

Expenses are directly related to the size of the population, and it is assumed that the county's officials attempt to match the typical expense rate of the governmental units in the environment on a per capita basis. By definition these expenses include both capital and operational

INTERNAL LOOPS--GOVERNMENT SECTOR



Note: External Influences

A. Population

1) + on expenses
2) + on assessed value
3) - on per capita expenses
4) + on projected expenses
5) + on other funds
6) + on projected other funds

B. Environmental Expenses

1) + on expenses

C. Environmental Other Funds

1) + on other funds

D. Housing Density

1) + on market value/acre

Figure 2. Influence Diagram.

Table 1. Government Sector--Constants

Constant Name	Value	Dimensions	Description
GACD	5	Years	Perception Time--Tax Ratio Needed
GADA	.0418	Dimensionless	Normal Millage Rate
GAHA	10,000	$/Acre	Scale Factor Market Value/Acre
GAND	1	Years	Projection Time--Population
GAQD	5	Years	Perception Time--Population
GAWD	1	Years	Projection Time--Per Capita Expenses
GAZD	2	Years	Perception Time--Per Capita Expenses

Table 2. Government Sector--"TABHL" Function Values

"TABHL" Function Value Name	Influencing Variable's Scale	Value	Dimensions	Description
GART*	(.5,5,.5)	.6/1/1.4/1.8/2.2/2.5/2.8/3/3.2/3.4	Dimensionless	Influence of the Tax Ratio Needed--Perceived on the Actual Tax Ratio
GAJT*	(.25,3,.25)	1.25/1.8/1.85/1.9/1.95/2/2.05/2.1/2.15/2.2/2.25/2.3	Dimensionless	Influence of the Housing Density on the Market Value/Acre
GAMT*	(0,100,10)	70/140/252/373/445/464/482/500/520/540/560.	$/Person/Year	Environmental Per Capita "Other Funds"
GART*	(-.1,.1,.02)	1.2/1.2/1.2/1.2/1.2/1.2/1.2/1.15/1.1/1.05/1/1	Dimensionless	Influence of the Debt Limit Comparison on the Revenue Rate
GPAT*	(0,100,10)	169/270/400/516/578/636/700/770/847/932/1025	$/Person/Year	Environmental Per Capita Expenses
GBRT*	(-.1,.1,.02)	.65/.65/.65/.65/.65/.75/.8/.85/.9/.95/1	Dimensionless	Influence of the Debt Limit Comparison on the Expense Rate

expenditures. They are "controlled" by the influence of the "debt limit comparison," which is the difference between the county's constitutionally imposed 14 percent debt to assessed value ratio and its actual debt to assessed-value ratio. The loop of which it is a part is a negative feed-back loop which "corrects" for any change introduced into it. As the county's debt to assessed-value ratio increases and the debt limit comparison decreases, tighter controls are placed on expenses, predominantly through delaying of capital expenditures. If the ratio increases further, potential expenses are lost due to the inablility of the government to float bond issues and to sell bond issues to investors. It is noted that increases in the county's assessed value tend to increase the debt limit comparison, thus slowing "control" measures.

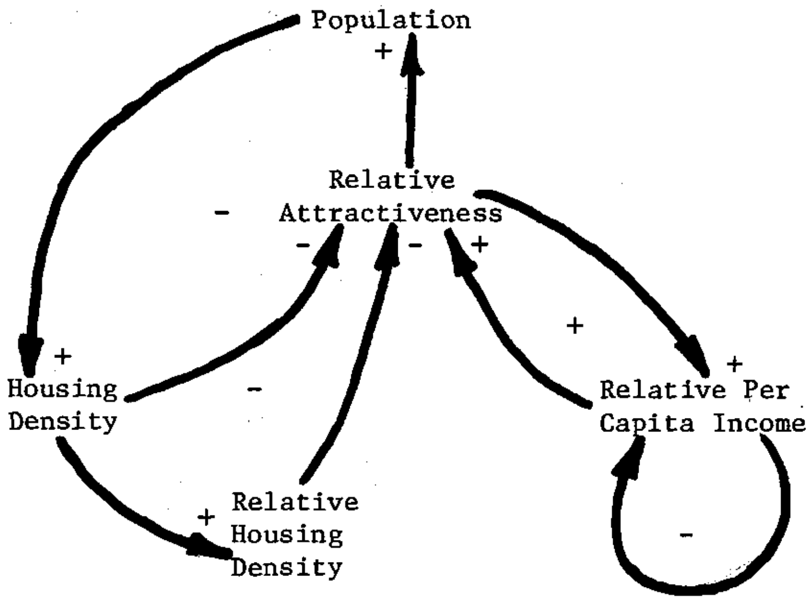
Revenues come from two sources, property taxes and "other funds" (service fees, license fees, and governmental transfers). The "other funds" are structured in much the same manner as expenses; they "match" the environment on a per capita basis, are "controlled" by the debt limit comparison, and in total, increase with increasing population size. A "per capita" concept is employed in this formulation due to the significant transfer of funds by the State government to the School Board on a per student basis and due to the significant fees collected by the county government on essentially a per household basis. As the debt limit comparison decreases, the amount of "other funds" increases, predoninantly through service fee increases. The property taxes collected in a given year vary from the taxes needed. The taxes collected are the product of the assessed value of real property and the actual millage rate. The millage rate used is the millage rate needed modified by the political pressure associated with raising taxes and slowed by the delay in perception of the government of the millage rate needed. The millage rate needed is the property taxes needed divided by the county's assessed value. The assessed value varies directly with the county's housing density, and decreases the millage rate needed if it increases. The property taxes needed are the product of the projected population of the county for the next year and the "net" of projections of the next year's per capita expenses and per capita "other funds." As the projected per capita expenses increase, the taxes needed increase; as the projected per capita "other funds" increase, the taxes needed decrease. It is assumed in this structure that the taxes needed, if collected, would allow the government to operate on a no-loss basis for the year in question.

Population Sector

The population sector is the most important sector in the model due to the widespread influence it exerts and due to the concepts upon which it is based. The sector represents the county's population, its housing density (both absolute and relative), and its relative per capita income. These are internally related (see Figure 3), and their influences basically determine the county's "relative attractiveness," which is a major factor in the yearly change of the county's population. Tables 3 and 4 display, respectively, the constants and "TABHL" function values present in the population sector.

As suggested earlier, the change in the county's population over time is a critical aspect of the model's behavior. The net yearly percentage change in the county's population is specified by 1) the defining of the system and its environment, and 2) the "relative attractiveness"

INTERNAL LOOPS--POPULATION SECTOR



Note: External Influences

A. Environmental %Δ Pop.-SMSA

1) + on rate of pop. change
2) - on rel. attrac. mult.
3) - on rel. attrac. scale

B. Environmental Housing Density

1) - on housing density ratio

C. % Vacant Land

1) - on housing density

Figure 3. Influence Diagram.

Table 3. Population Sector--Constants

Constant Name	Value	Dimensions	Description
PAAD	10	Years	Perception Time--Relative Attractiveness
PAJA	.32	House/Person	Normal Per Capita Housing
PAUD	1	Years	"Last Year"

Table 4. Population Sector—"TABHL" Function Values

"TABHL" Function Value Name	Influencing Variable's Scale	Value	Dimensions	Description
PACT*	(.005,.03,.005)	5.85/2.94/1.97/1.48/1.23/1	Dimensionless	Influence of the SMSA % change in population on magnitude of county's relative attractiveness (Type 1)
PADT*	(0,100,10)	.03/.0275/.025/.0225/.02/.0175/.015/.0125/.01/.0075/005	%/Year	Environmental yearly percentage change in population
PAET*	(.91,1.09,.02)	-2/-1.33/-.67/0/.67/1.33/2/2.67/3.33/4	Dimensionless	Relative Attractiveness conversion table
PAGT*	(.005,.08,.005)	.025/.02/.015/.01/.005/o	%/Year	Influence of the SMSA % change in population on the county's relative attractiveness (Type 2)
PAHT*	(.2,2,.2)	.96/.89/.84/.83/.825/.82/.815/.81/.805/.8	Dimensionless	Influence of the absolute housing density on relative attractiveness
PAKT*	(0,1,.2)	1/.97/.95/.93/.91/.9	Dimensionless	Influence of the percentage vacant land on per capita housing
PALT*	(.2,2,.2)	1.2/1.175/1.14/1.11/1.07/1.03/1.02/1.01	Dimensionless	Influence on the relative housing density on relative attractiveness
PANT*	(0,100,10)	.28/.41/.6/.75/.92/1.1/1.3/1.47/1.61/1.73/1.82	House/Acre	Environmental housing density
PAPT*	(.8,1.15,.05)	.88/.93/.96/.98/1/1.1/1.105/1.11	Dimensionless	Influence of the relative per capita income on relative attractiveness
PAST*	(-4,6,1.67)	.999/.9995/1/1/1/1.0034/1.0068	Dimensionless	Influence of the relative attractiveness on the change in the relative per capita income
PATT*	(.85,1.25,.05)	1/1/1/1/.998/.996/.994/.992/.99	Dimensionless	Influence of the previous year's relative per capita income on the change in relative per capita income

concept. The yearly percentage change of the environment multiplied by the influence of the county's attractiveness relative to the environment (as perceived by potential migrants) and by the county's current population size consitute the county's yearly population change. The environment's yearly percentage change is initially three percent growth per year and gradually decreases over the course of the simulation. Discussion of this assumption is contained in Chapter V. If the perceived relative attractiveness of the county is greater than that of the environment, the county's yearly percentage rate of change in population is higher than that of the environment. The county's relative attractiveness is a combination of four influences; those of the county's absolute housing density, its relative housing density, its relative per capita income, and the environment's yearly percentage change in population. As with the "millage needed" in the Government Sector, the actual relative attractiveness must be perceived (by potential migrants). This dampens changes in the actual relative attractiveness and introduces a time lag into the sector.

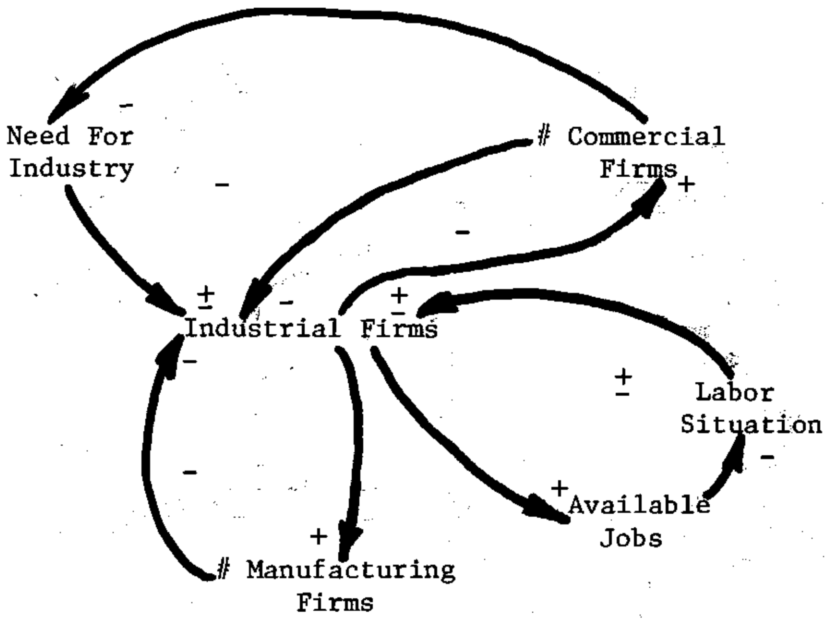
Figure 3 illustrates the primary internal feedback loops of the Population Sector and shows the influences of variables external to the sector on variables within the sector. As shown, both the absolute and relative housing densities of the county are negatively related to its relative attractiveness. As they increase, the county's relative attractiveness decreases, thereby reducing growth in population size. The relative per capita income is positively related to the county's relative attractiveness. An increase in relative per capita income accelerates population growth by increasing the county's relative attractiveness.

It is seen that the relative attractiveness is positively related to the relative per capita income and thus forms a positive loop. The size of the relative per capita income in a given year tends to depress increases in it in the next year if it is sufficiently high. Several influences of variables external to the sector are significant. The environment's yearly percentage change in population exerts influence on the county's relative attractiveness. As it changes, the base upon which the county's attractiveness is compared changes. As the environment's yearly percentage change decreases, the county's relative attractiveness is inflated. The environment's housing density decreases the county's relative housing density if it increases, thus increasing the county's relative attractiveness. The percentage of vacant land in the county causes an increase in the county's housing density as it decreases, producing a decrease in relative attractiveness.

Industrial Sector

The Industrial Sector represents the commercial and manufacturing firms present in the county and their related jobs. Both the "labor situation" in the county and the county's "need for industry" are given as well as their influences on the yearly change in the number of industrial firms in the county. The "labor situation" in the county is defined as the difference between available labor and available jobs, expressed as a percentage of the county's population. The county's "need for industry" is the difference between the normal number of commercial firms per capita (a composite average based on data from 90 representative counties) and the county's actual number of commercial firms per capita. Figure 4 illustrates the internal feedback loops of the Industrial Sector

INTERNAL LOOPS--INDUSTRY SECTOR



Note: External Influences

A. Population

1) + on labor situtation
2) - on L.S. as a % of pop.
3) - on comm. firms/per

B. Income Ratio

1) $\pm$ on labor force (L.S.)

Figure 4. Influence Diagram.

and lists the external influences on it. As in the prior sector descriptions, Tables 5 and 6 list the constants and "TABHL" function values contained in the sector, respectively.

Unlike the net yearly percentage change in the population, the net yearly percentage change of industrial firms in the county is formulated directly. However, it is delayed in a manner similar to that of the actual relative attractiveness in the Population Sector. The net yearly percentage change of industrial firms is the sum of the influences of the county's "need for industry" and its "labor situation," modified by the influences of the number of commercial and manufacturing firms present in the county, respectively. The influences of the number of commercial and manufacturing firms represent the effects of competition. As the number of firms increases, the pressure exerted by their competition reduces movement of new firms into the county. The county's "need for industry" is positively related to the net yearly percentage change of industrial firms in the county. As the "need for industry" increases, so does the net yearly percentage change. Naturally as the need is filled, the net yearly percentage change decreases. The county's "labor situation" causes the net yearly percentage change to increase as it increases, up to a point. At this point its influence becomes negative, reflecting an oversupply of labor. As Figure 4 would indicate, commercial firms respond to the county's "need for industry," while manufacturing firms act in accordance to the "labor situation."

Of the external influences on the Industrial Sector, the population size's influence on the "need for industry" is the most important. As the population of the county increases, the "need for industry"

Table 5. Industrial Sector--Constants

Constant Name	Value	Dimensions	Description
IAAD	5	Years	Delay Time--Rate of Change--Industry
IAEA	.001	Dimensionless	Scaling Factor
IAFA	.94	Dimensionless	Normal % of Commercial Firms
IAHA	.018	Commercial Firms/ Person	Normal Commercial Firms Per Capita
IASA	22	Jobs/Industrial Firm	Normal Jobs/Industrial Firm
IATA	.382	Dimensionless	Normal % of the Population Which is the Labor Force

Table 6. Industrial Sector--"TABHL" Function Values

"TABHL" Function Value Name	Influencing Variable's Scale	Value	Dimensions	Description
IADT*	(2,16,2)	3.5/1.8/1.3/1.2/1.1/1/1.7/25	Dimensionless	Influence of the Number of Commercial Firms on the % change of Industrial Firms
IAGT*	(-.006,.008,.002)	-.013/-.007/-.003/.002/.011/.016/.018/.019	%/Year	Influence of the Need for Industry on the % Change of Industrial Firms
IALT*	(0,1.5,.5)	7.8/5.5/1/3.9	Dimensionless	Influence of the Number of Manufacturing Firms on the % Change of Industrial Firms
IAPT*	(-.075,.15,.025)	.0002/.0005/.0007/.002/.0017/.0016/.0015/.0013/.0011/.0009	%/Year	Influence of the Labor Situation on the % change of Industrial Firms
IAUT*	(.85,1.15,.05)	.96/1/1.03/1.02/1.005/.99/.975	Dimensionless	Influence of the Relative Per Capita Income on the % of the Population in the Labor Force

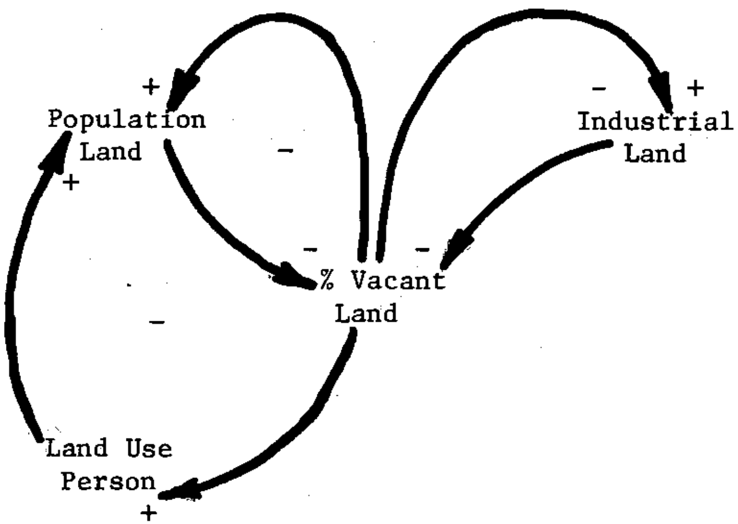
increases. The population size influences the labor situation in both a positive and negative manner. It is positively related to the labor force and negatively related to the "labor situation," as it is a divisor in the formulation. The relative per capita income causes an increase in the percentage of the population which constitutes the labor force as it increases until the effects of affluence reverse its influence.

Land Sector

The land sector depicts the land use in the county by the categories of populated, industrial, and vacant land. Populated land consists of residentially zoned and occupied land. Industrial land is both commercially and industrially zoned land which is in use, and vacant land is land which may be zoned but is not actually in use. Figure 5 shows the sector's internal feedback loops and lists the influences of variables external to it. Tables 7 and 8 list the constants and "TABHL" function values of the land sector, respectively.

There is only one significant internal feedback loop in the land sector. This loop is the one in which the rate of change of population land is slowed by a decreasing per capita land use as the percentage of vacant land decreases. This reflects changing building patterns as land becomes less available (more multi-family residential construction). The remainder of the influences are external to the sector. The rates of change of both populated and industrial land are positively related to the yearly changes of population and industry. As the yearly changes of population and industry increase, the rates of change of their respective land use increase, and the percentage of vacant land decreases. In addition the rates of change of land use are influenced by the per acre

INTERNAL LOOPS--LAND SECTOR



Note: External Influences

A. Population

1) + on rate of change--
pop. land

B. Industry

1) + on rate of change--
pop. land

C. Market Value/Acre

1) - on rate of change--
pop. land

2) - on rate of change--
ind. land

Figure 5. Influence Diagram.

Table 7. Land Sector--Constants

Constant Name	Value	Dimensions	Descriptions
LADD	1	Years	"Previous Year"
LAEA	.146	Acres/Person	Per Capita Land Use
LAGA	172,000	Acres	Total Land Area
LBAA	1.3	Acres/Industrial Firm	Land Use/Industrial Firm
LBDD	1	Years	"Previous Year"

Table 8. Land Sector--"TABHL" Function Values

"TABHL" Function Value Name	Influencing Variable's Scale	Value	Dimensions	Description
LABT*	(0,50000,10000)	1/.9/.8/.5/.2/.1	Dimensionless	Influence of Market Value Per Acre on the Rate of Change of Populated Land
LAFT*	(0,1,.2)	.7/.75/.8/.85/.9/1	Dimensionless	Influence of the Percentage of Vacant Land on Per Capita Land Use
LBBT*	(0,50000,10000)	1/1/.9/.8/.5/.2	Dimensionless	Influence of Market Value Per Acre on the Rate of Change of Industrial Land

market value of the land. As the market value increases, fewer and fewer buyers are found, thus limiting growth.

CHAPTER III

RESULTS

As stated previously, the simulation of the model was carried out on the Georgia Institute of Technology's Univac 1108 computer. The figures contained in this chapter are reproductions of the graphical output (plots) of the simulation. In addition, tables are provided which display the behavior of the model in numerical terms. The general behavior of the model will be discussed first, followed by a more detailed analysis of the behavior of each sector. The reader may wish to skip the detailed discussion and move to the next chapter.

Figure 6 displays the behavior of the major variables of the model over the 100 years of the simulation, while Table 9 presents their behavior numerically. As can be seen, each of the variables goes through three phases; an initial growth phase (except for the percentage of vacant land which declines), a slight declining phase, and another growth phase. Each of these phases will be described separately, and the reader is urged to refer to Figure 6 and Table 9 to maintain his overall perspective. In Table 9 it should be noted that the letter "E" denotes the exponent (base 10) to which the preceding number is raised. For example, 24E6 is equivalent to 42,000,000.

General Behavior

The simulation of the model begins in 1960 and proceeds for 100 years. Initially the relative attractiveness of DeKalb County as

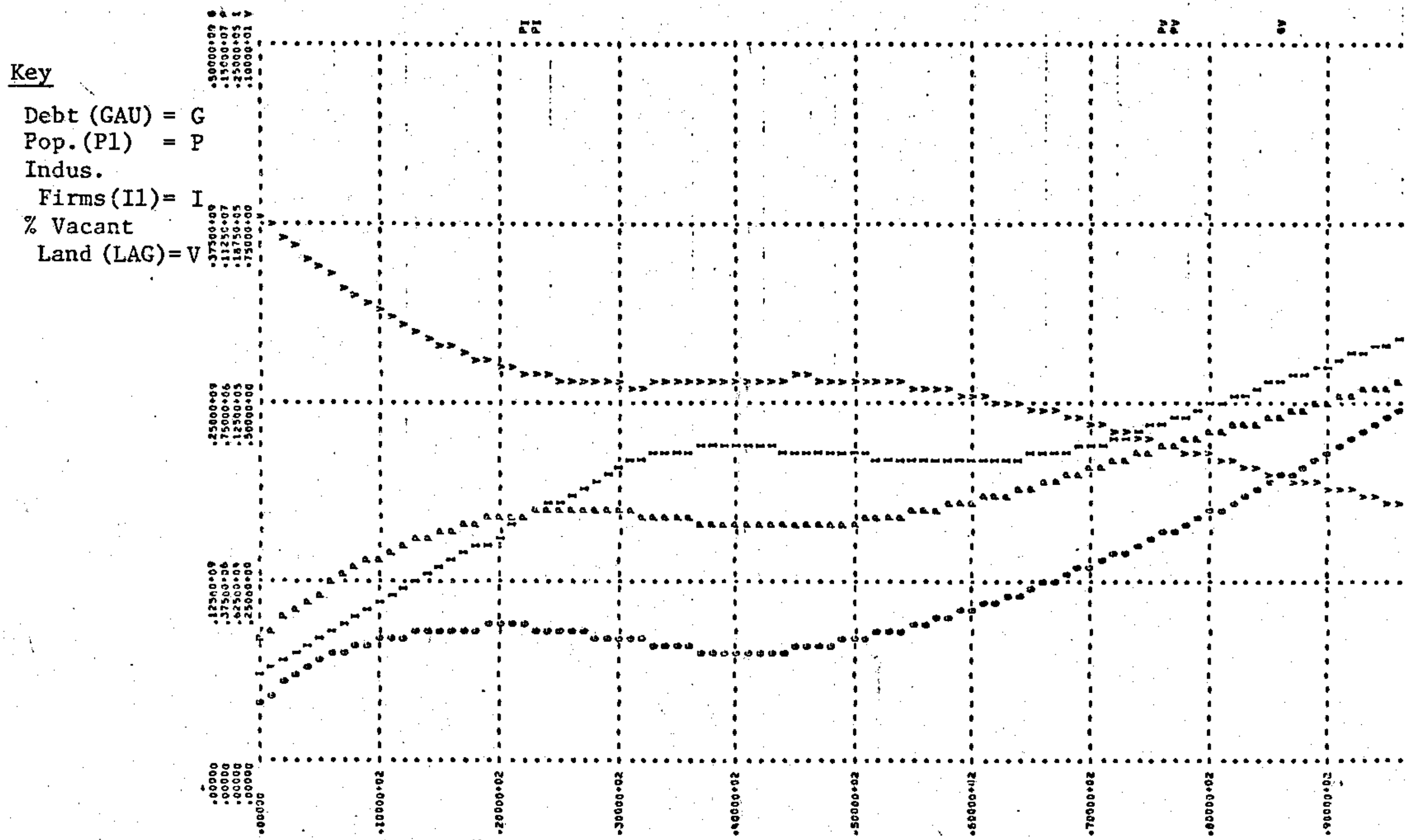


Figure 6. General Behavior--DeKalb County Model.

Table 9. Behavior--DeKalb County Model

	1960	1970	1987	2004	2040
Debt (G1)	42E6	75E6	90E6	81E6	177E6
Taxes Needed (GAK)	25E6	41E6	42E6	41E6	77E6
Taxes Collected (GAA)	15E6	38E6	46E6	41E6	74E6
"Net" Per Capita Proj. (GXX)	91	92	81	84	112
Debt Limit Comparison (GAS)	.055	.060	.063	.067	.030
Population (P1)	2.6E5	4.3E5	5.2E5	4.9E5	6.8E5
Perceived Rel. Attrac. (PAA)	2.50	1.03	-.04	-.04	1.06
Actual Rel. Attrac. (PAB)	.93	-.02	-.46	.49	1.13
Rel. Per Capita Income (PAQ)	1.09	1.06	1.03	1.01	1.00
Housing Density (PAJ)	.44	.74	.91	.86	1.20
Industrial Firms (I1)	2.9E3	5.4E3	9.6E3	10.9E3	12.4E3
Delayed % Change (IAA)	.080	.046	.024	-.003	.012
Actual % Change (IAB)	.061	.036	.011	-.004	.012
Need for Industry (IAH)	.007	.006	.001	-.003	.001
Labor Situation-% of Population (IAQ)	.129	.105	-.018	-.096	-.001
Fraction Vacant Land (LAG)	.76	.63	.53	.53	.43
Market Value/Acre (GAH)	7.3E3	13.6E3	17.1E3	16.1E3	23.4E3
Population Change (LAC)	12.0E3	13.2E3	0E3	-.1E3	7.3E3
Industrial Firms Change (LBC)	220	249	240	- 25	154
Environmental % Pop. Change (PAD)	.0300	.0275	.0233	.0190	.0100
Environmental Housing Density (PAN)	.28	.41	.71	.99	1.61

perceived by potential migrants is extremely high, while the actual relative attractiveness is almost neutral. The lag in the potential migrants' perception of the county's relative attractiveness and the high rate of growth of the Atlanta metropolitan area sustain growth in the county until 1987. As the county's population increases during this period, the actual relative attractiveness decreases even further. This is due to the decrease in the influences of the county's housing density and its relative per capita income on the county's actual relative attractiveness. The decrease in influence of these variables is caused by the increasing population (and resultant housing density) and the county's initially high relative per capita income, respectively. During this period the government experiences an increase in debt, caused partially by the increasing population. An increasing difference between per capita expenses and per capita "other funds," coupled with the delay associated with the government's perception of the taxes needed contributes to the debt increase also. It is seen that the debt limit comparison increases, even though the government's debt increases. This is caused predominantly by an increase in the assessed value of real property in the county which decreases the county's debt to assessed value ratio. It has the effect of decreasing revenues and loosening controls on expenses. The increase in debt stops in 1981, six years prior to the population peak, because of the slow rate of change of the population and the start of a decline in the difference between per capita expenses and per capita "other funds," which enable the government to effectively collect the taxes it needs. Industrial firms are attracted to the county by the county's high need for industry, its favorable labor situation, and the low competition which exist in 1960. As in the case of the county's relative attractiveness, the delayed percentage change of industrial firms is initially higher than the actual percentage change and decreases as industrial firms move into the county. The increasing population sustains both the county's need for industry and its favorable labor situation from 1960 to 1987, but as the population growth slows, the need for industry becomes filled more rapidly, the labor situation deteriorates, and the effects of competition are felt. Industry growth is stopped by these factors in the year 2000, thirteen years after the population peak. The land use in the county during its initial growth phase naturally varies with the growth of population and industrial firms. The percentage of vacant land reaches a temporary low of 52 percent in 1992, reflecting the continuing growth of industry after the population peak. The increasing market value per acre slows the use of land, as does the decreasing land use per person.

From 1987 to 2004 the population of the county decreases slightly due to a very low perceived relative attractiveness. The low perceived relative attractiveness is the result of the high housing density of the county and its decreased relative per capita income. The causes behind these conditions are similar to those described in the preceding paragraph. It is noted, however, that the higher rate of growth in the other portions of the metropolitan area cause the county's relative housing density to decrease, thereby raising its influence on the relative attractiveness. This occurrence, in conjunction with the lowering of the county's absolute housing density halt the decline in population in 2004. The government's debt decreases from 1981 to 2001 due to the decreasing population as well as the decreasing difference in per capita expenses and per capita "other funds." As in the growth phase, the government's perception delay associated with taxes needed causes a discrepency to exist between taxes collected and taxes needed, in this instance in the positive direction. As the population decreases, the county's need for industry decreases and a labor shortage occurs. This causes the number of industrial firms in the county to decline slightly from 2000 to 2018. The delays present in the industrial and population sector are reflected in the 14-year lag of the industrial firm "minimum" behind the population "minimum." The percentage of vacant land, following the population and industrial firms' trends, increases to 54 percent in 2006.

From 2004 until the end of the simulation (2060), the county's population increases, primarily due to conditions in the remainder of the metropolitan area. The county's relative housing density decreases due to the development occurring elsewhere in the Atlanta metropolitan area, thus resulting in an increasing relative attractiveness. The county's relative per capita income decreases until it matches that of the environment, becoming a neutral factor in the county's relative attractiveness. The rate of growth of the county's population, however, is low percentage-wise because of the low rate of growth of the Atlanta area. The debt of the county government increases from 2001 to 2060 for the same reasons mentioned in the description of the initial growth phase. However, during this period the assessed value of the county's real property does not increase rapidly enough (due to the slower population growth) to prevent the debt limit comparison from decreasing. This results in an ever-increasing attempt to secure "other funds" and a continuing tightening of controls on expenses. As the population grows, industrial firms are once more attracted to the county by an increasing need for industry and favorable labor situation. The growth is slowed by the slow population growth as well as the competition from the large number of firms residing in the county. The land use, as in other phases, parallels the growth of population and industry. However, the high market value per acre of land and the lowered per capita land use slow the decrease in the percentage of vacant land.

Government Sector

The behavior of the important variables in the government sector over the course of the simulation is illustrated graphically in Figure 7 and given numerically in Table 10.

The government's cash balance decreases from 1960 to 1981 due to the manner in which it responds to the increasing difference in per capita expenses and "other funds," magnified by an increasing population. The government's response is determined in part by the influence of its debt position (ratio of debt to assessed value) has on the control of revenues and expenses and in part of environmental conditions. Initially the millage rate of the county is extremely low with respect to the typical rate of other governmental units in the metropolitan area, and there is a strong tendency to increase revenues by tax increases. In addition, the county's market value per acre increases rapidly due to the increasing housing density caused by population growth. This decreases the debt to assessed value ratio, which has the effect of slowing increases in "other fund" revenues via increases in service fees. Thus, tax increases are favored over service fee increases, as the dramatic increase in the

Key

Debt(GAU) = G
"Net"(GXX) = N
Pop.(P1) = P
Debt Limit
Comparison
(GAS) = C

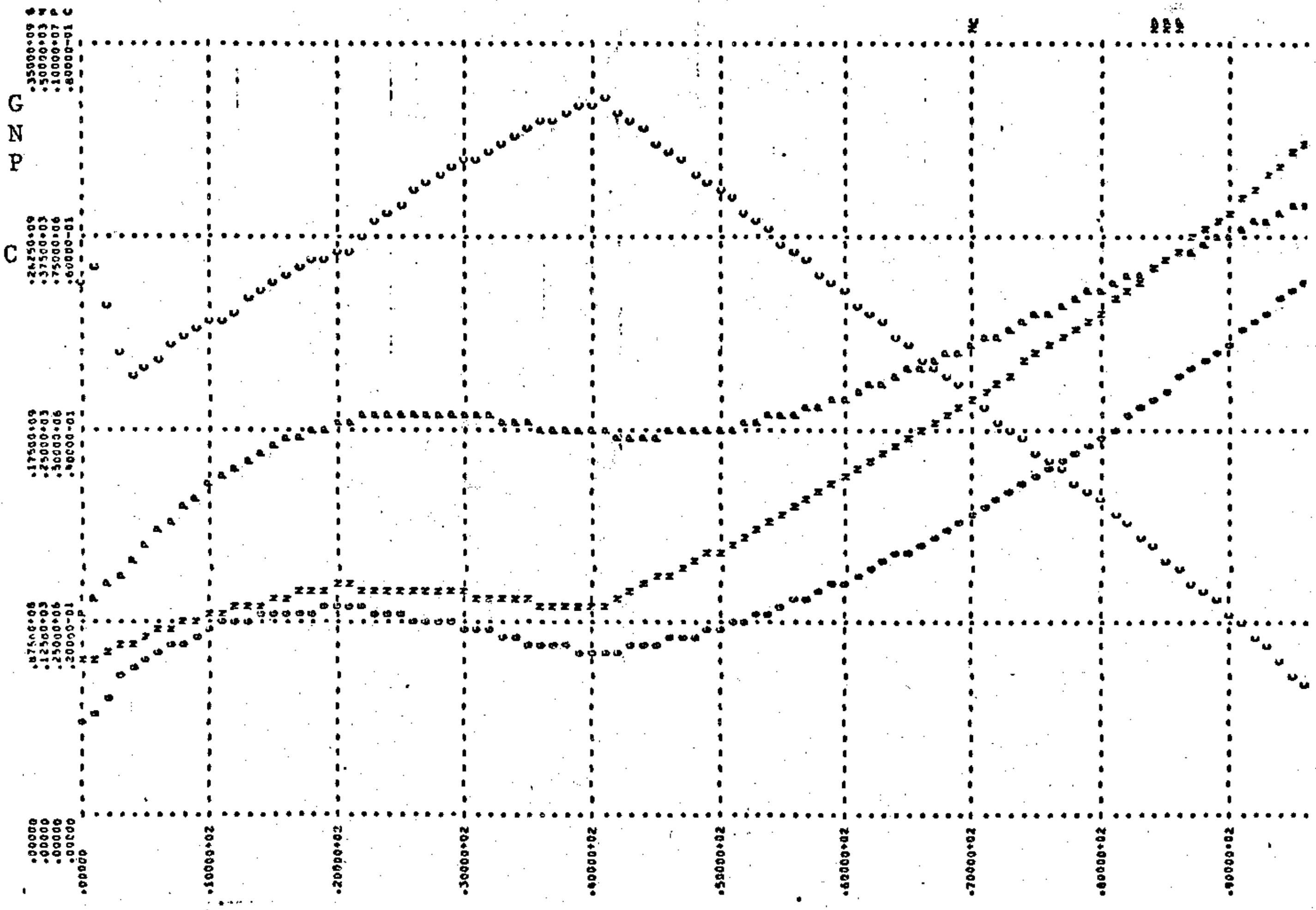


Figure 7. Behavior--DeKalb County Model, Government Sector.

Table 10. Behavior--Government Sector

	1960	1970	1981	2001	2040
Debt (GAU)	42E6	75E6	93E6	78E6	177E6
Revenue Rate (GA)	34E6	101E6	190E6	267E6	475E6
Other Funds (GXB)	19E6	63E6	143E6	227E6	401E6
Per Capita Other Funds (GAM)	70	140	264	447	520
Debt Limit Comp. Infl. (GAR)	1.06	1.05	1.05	1.02	1.13
Taxes (GAA)	15E6	38E6	47E6	40E6	74E6
Tax Ratio (GAB)	.73	.97	.98	.86	1.10
Millage Needed (GAE)	.049	.044	.039	.036	.048
Taxes Needed (GAK)	25E6	41E6	45E6	40E6	77E6
"Net" Per Capita Proj. (GXX)	91	92	87	82	112
Market Value/Acres (GAH)	7.3E3	13.6E3	16.7E3	16.1E3	23.4E6
Expense Rate (GB)	39E6	104E6	190E6	269E6	479E6
Per Capita Expense Rate (GBA)	169	270	412	584	847
Debt Limit Comp. Infl. (GBB)	.89	.90	.90	.93	.82
Population (P1)	2.6E5	4.3E5	5.2E5	4.9E5	6.8E5
Projected Population (GAN)	27E5	4.4E5	5.2E5	5.0E5	6.9E5
Housing Density (PAJ)	.44	.74	.91	.86	1.20

tax ratio from 1960 to 1970 (.73 to .97) indicates. However, the delay and political difficulty associated with tax increases prevents the taxes collected from reaching the level needed to avoid an increase in debt during this period. It is noted that the budgeting procedure is fairly accurate and does not contribute significantly to the increase in debt.

From 1981 to 2001 the difference between per capita expenses and other funds decreases, and the county's population decreases. These occurrences cause the government to actually decrease its debt since its revenues are too high and the response to changing conditions in the tax loop is slow. However, controls on expenses are loosened and service fees are decreased because of the decreasing debt to assessed value ratio. The market value per acre is decreasing during this period due to a declining declining population, which slows the decrease in the aforementioned ratio.

The county's debt increases from 2001 to 2060 under the same influences present from 1960 to 1981. However, the government's approach in coping with the situation differs. Although the market value per acre increases, it is not enough to prevent the debt to assessed value ratio from increasing. This produces tighter controls on expenses and increases in service fees. Toward the latter stages of the simulation the service fee increases approach their limit and tax increases are preferred to them. However, the political difficulties related to these tax increases become increasingly prevalent and slow the increases.

<u>Population Sector</u>

The behavior of the important variables of the population sector are shown in Figure 8 and Table 11. Reference to these, as well as Figure 3 will be of value to the reader.

In 1960 the perceived relative attractiveness of the county is very high (2.50 which implies a yearly percentage growth of 7.5 percent), but the actual attractiveness is almost neutral. The high perceived relative attractiveness and the high rate of growth of the Atlanta area prolong growth in the county's population until 1987, at which time the population begins to decline. Table 11 shows that the component parts of the relative attractiveness are changing in response to changes in the county. The increasing housing density is creating a larger negative influence on the county's relative attractiveness during this period. As the income ratio decreases, due to its initial large size, its positive influence on the relative attractiveness decreases. These two influences produce the decrease in actual relative attractiveness from 1960 to 1991. The condition of the metropolitan area exerts a positive influence on the county's relative attractiveness in two ways. First, as the metropolitan area's housing density increases faster than the county's (1971 to 1987), the county's relative housing density decreases, producing a slightly greater positive influence on its relative attractiveness. Secondly, the decreasing rate of change of the metropolitan area's population "inflates" the county's relative attractiveness, by definition. This is true throughout the length of the simulation and is especially evident in the later stages. The lag in response to changes in the actual relative attractiveness is due to potential migrants' delay in perceiving the actual state of the county and then reacting to it.

From 1987 to 2004 the county's population decreases due to a very

Key

Pop.(P1) = P
Rel.Attrac.
(PAB) = A
Housing Den.
Influence
(PXA) = H
Rel. Per
Cap.Income
Infl.(PAP) = I
% Change Pop.
SMSA Infl.
(PAG) = S

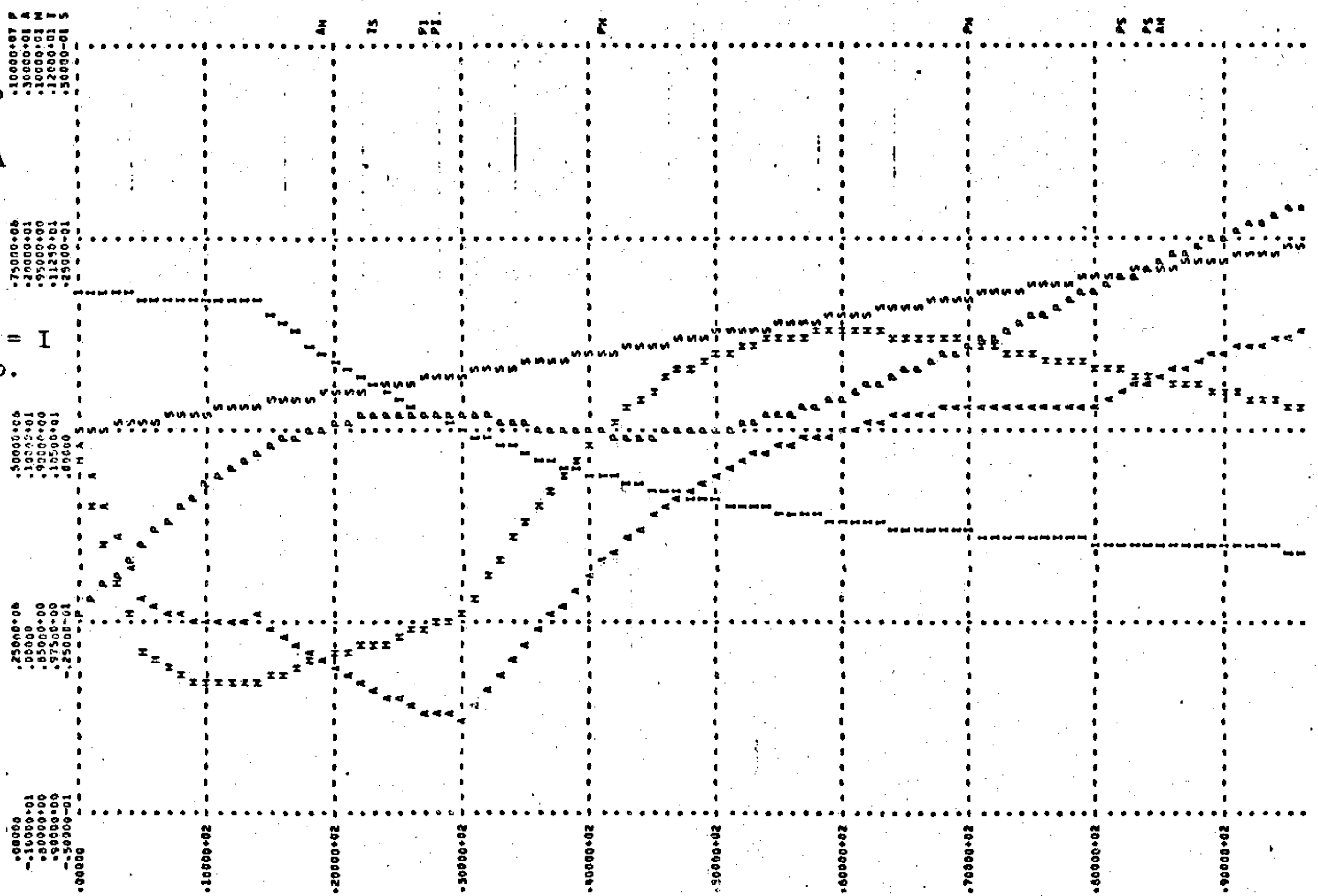


Figure 8. Behavior--DeKalb County Model, Population Sector.

Table 11. Behavior--Population Sector

	1960	1970	1987	2004	2040
Population (P1)	2.6E5	4.3E5	5.2E5	4.9E5	6.8E5
Perceived Rel. Attrac. (PAA)	2.50	1.03	-.04	-.04	1.06
Actual Rel. Attrac. (PAB)	.93	-.02	-.46	.49	1.13
Housing Densities" Infl. (PXA)	.89	.83	.85	.91	.92
Rel. Per. Capita Income Infl. (PAP)	1.10	1.10	1.06	1.03	1.01
% Change S.M.S.A. Infl. (PAG)	.0000	.0025	.0068	.001	.02
% Change S.M.S.A. Mult. (PAC)	1.00	1.12	1.32	1.58	2.94
Absolute Housing Density (PAJ)	.44	.74	.91	.86	1.20
Relative Housing Density (PAM)	1.56	1.80	1.29	.87	.75
Relative Per. Capita Income (PAQ)	1.09	1.06	1.03	1.01	1.00
Rel. Attrac. Infl. (PAS)	1.00	1.00	1.00	1.00	1.00
Size Infl. (PAT)	.996	.998	.999	.999	1.00

low perceived relative attractiveness. The actual relative attractiveness, as mentioned above, had been decreasing since 1960, and in 1975 it became negative (indicating a decrease in population). The maximum rate of decrease is reached in 1996, when the perceived relative attractiveness begins to increase. This increase is due solely to the changing condition of the metropolitan area. An increasing housing density in the metropolitan area is reducing the county's relative housing density, which increases the county's relative attractiveness. In addition, the decreasing rate of change of the metropolitan area's population enhances the county's relative attractiveness. It is noted that the county's income ratio continues to decrease by virtue of its relatively high level. In 2004 the population begins to increase due to the positive influence of the metropolitan area's condition.

The trend from 2004 until 2060 is similar to that mentioned in the preceding paragraph. Both the actual and perceived attractiveness of the county grow due to conditions external to the county. As in prior periods, the decreasing rate of change of the metropolitan area's population continues to inflate the county's relative attractiveness. The negative influence of the county's increasing housing density is counterbalanced by the positive influence of its decreasing relative housing density. During this time the county's relative per capita income becomes a neutral factor in determining the county's relative attractiveness.

Industrial Sector

As is the case of the relative attractiveness of the Population Sector, the actual yearly percentage change of industrial firms in the county is delayed (by the time it takes for a location decision to be formulated and implemented). Initially the delayed percentage change is high, while the actual percentage change is somewhat lower. This prolongs growth of industrial firms, as did the perceived relative attractiveness in the initial growth phase of the population. Figure 4 shows that the commercial firms are associated with the need for industry, whereas manufacturing firms are associated with the labor situation. Initially both the need for industry and the labor situation are favorable, and the population growth until 1987 sustains their high level. However, as the population growth slows, the need for industry becomes more rapidly filled, and the labor situation deteriorates. Consequently, growth of industrial firms is halted in the year 2000. It is seen that the number of industrial firms in the county is small, and consequently competition is low. This situation magnifies the percentage change of industrial firms, but as the number of firms increases, this multiplier effect decreases. Figure 9 and Table 12 depict the behavior of the industrial sector graphically and numerically, respectively.

Between 2000 and 2018 the number of industrial firms declines due to the delayed effects of a decreasing population. It takes 13 years for the need for industry to become filled after the population stops growing. At this point the county is "saturated" with commercial firms which have created a labor shortage, thereby depressing growth of manufacturing firms. As the population begins to increase in 2004 and the number of industrial firms continues to decrease, the need for industry increases. Also the shortage of labor becomes less intense as jobs decrease when firms leave the county. This spurs growth of manufacturing

Key

Indus. Firms
(I1) = I
% Change
(IAB) = A
Need for Ind.
Influence
(IAC) = C
Labor Situ.
Influence
(IAK) = M

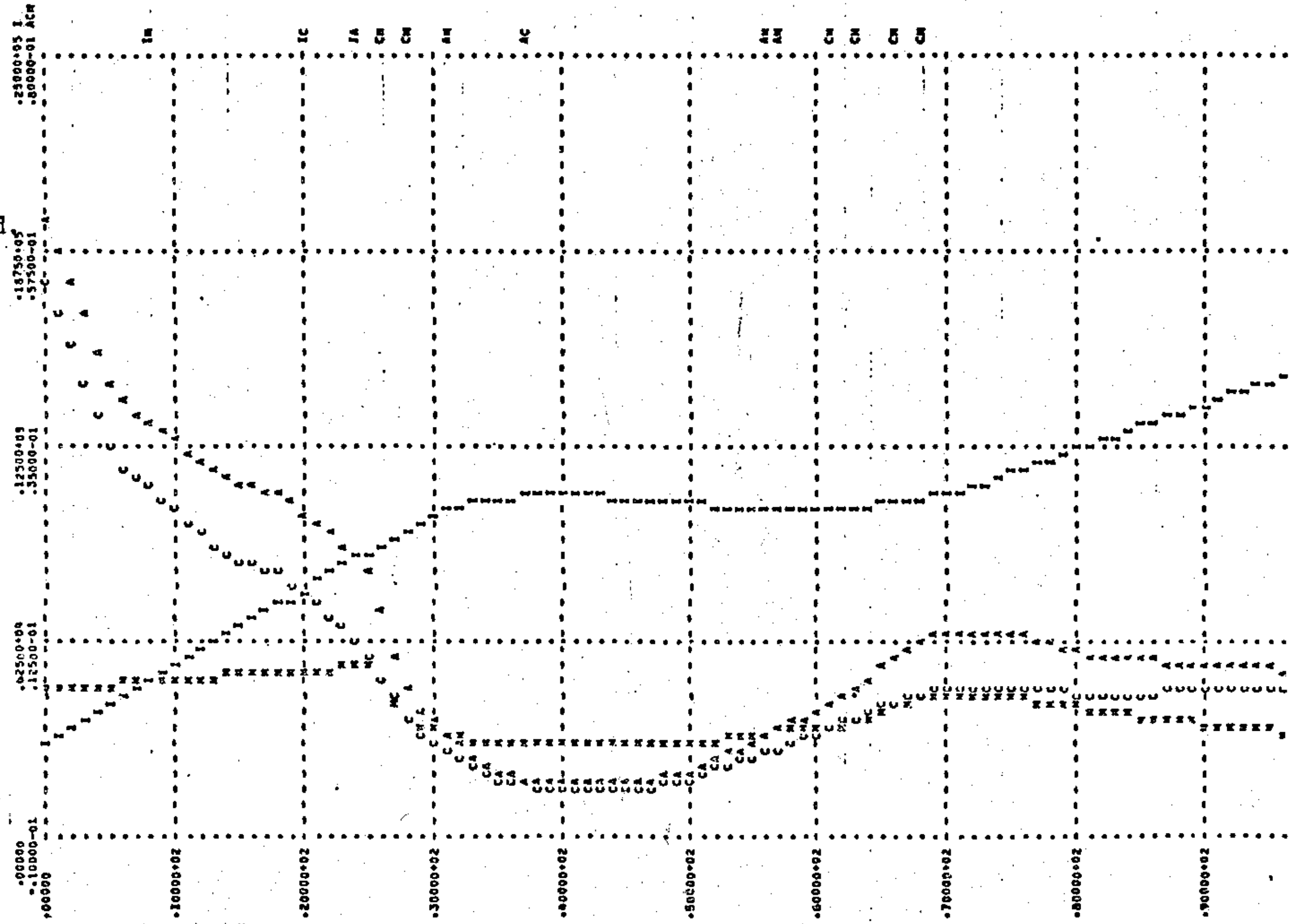


Figure 9. Behavior--DeKalb County Model, Industrial Sector.

Table 12. Behavior--Industrial Sector

	1960	1970	2000	2018	2040
Industrial Firms (I1)	2.9E3	5.4E3	10.9E3	10.5E3	12.4E3
Delayed % Change (IAA)	.080	.046	-.001	.000	.012
Actual % Change (IAB)	.061	.036	-.004	.002	.012
Need for Industry Infl. (IAC)	.053	.028	-.005	.001	.006
# Commercial Firms Infl. (IAD)	2.87	1.53	1.09	1.11	1.02
Actual Need for Industry Infl. (IAG)	.019	.018	-.004	.001	.006
Labor Situation Infl. (IAK)	.008	.008	.001	.001	.006
# Manufacturing Firms Infl. (IAL)	6.99	6.31	4.09	4.33	3.32
Actual Labor Situation Infl. (IAP)	.0011	.0013	.0002	.0005	.0015
# Commercial Firms (IAF)	2.7E3	5.1E3	10.3E3	9.9E3	11.6E3
# Manufacturing Firms (IAN)	.2E3	.3E3	.6E3	.6E3	.8E3
Need for Industry (IAH)	.007	.006	-.003	.000	.001
Labor Situation--% of Pop. (IAQ)	.129	.105	-.097	-.044	-.001
Population (P1)	2.6E5	4.3E5	5.0E5	5.3E5	6.8E5
Relative Per Capita Income Infl. (IAU)	.99	1.00	1.02	1.02	1.02

firms. In 2018, 14 years after the population decline stopped, these influences cause the decrease of industrial firms to cease.

From 2018 to 2060 the growth of industrial firms continues, due predominantly to population growth which maintains a continuing need for industry and a favorable labor situation. It is noted that the rate of change is relatively low because of the low rate of change of the population, the increased effect of competition, and the near steady-state condition of the county with respect to its need for commercial firms.

Land Sector

Figure 10 shows the behavior of important variables of the Land Sector graphically. The same data are shown numerically in Table 13. As can be seen, the Land Sector responds directly to changes in population and the number of industrial firms. The percentage of vacant land in the county decreases from 1960 to 1992 as the population and number of industrial firms grow. It reaches a temporary minimum five years after the population peaks due to the continued increase in the number of industrial firms. The decrease in the percentage of vacant land is slowed by the influence of market value per acre and by a decreasing per capita land use.

The percentage of vacant land increases slightly (52 to 54 percent) until 2006 due to the decreasing population and number of industrial firms. However, as the population and number of industrial firms begin to increase in 2004 and 2018, respectively, the percentage of vacant land once again decreases. As the percentage of vacant land decreases, the per capita land use decreases, thus slowing the rate of use. The market value per acre provides an even more limiting influence on the rate of land use in this period than it did previously.

Key

% Vacant Land (LAG) = V

Pop. Change (LAC) = P

Ind. Firm Change (LBC) = I

Market Value Infl.-Pop. Land (LAB) = A

Market Value Infl.-Ind. Land (LBB) = B

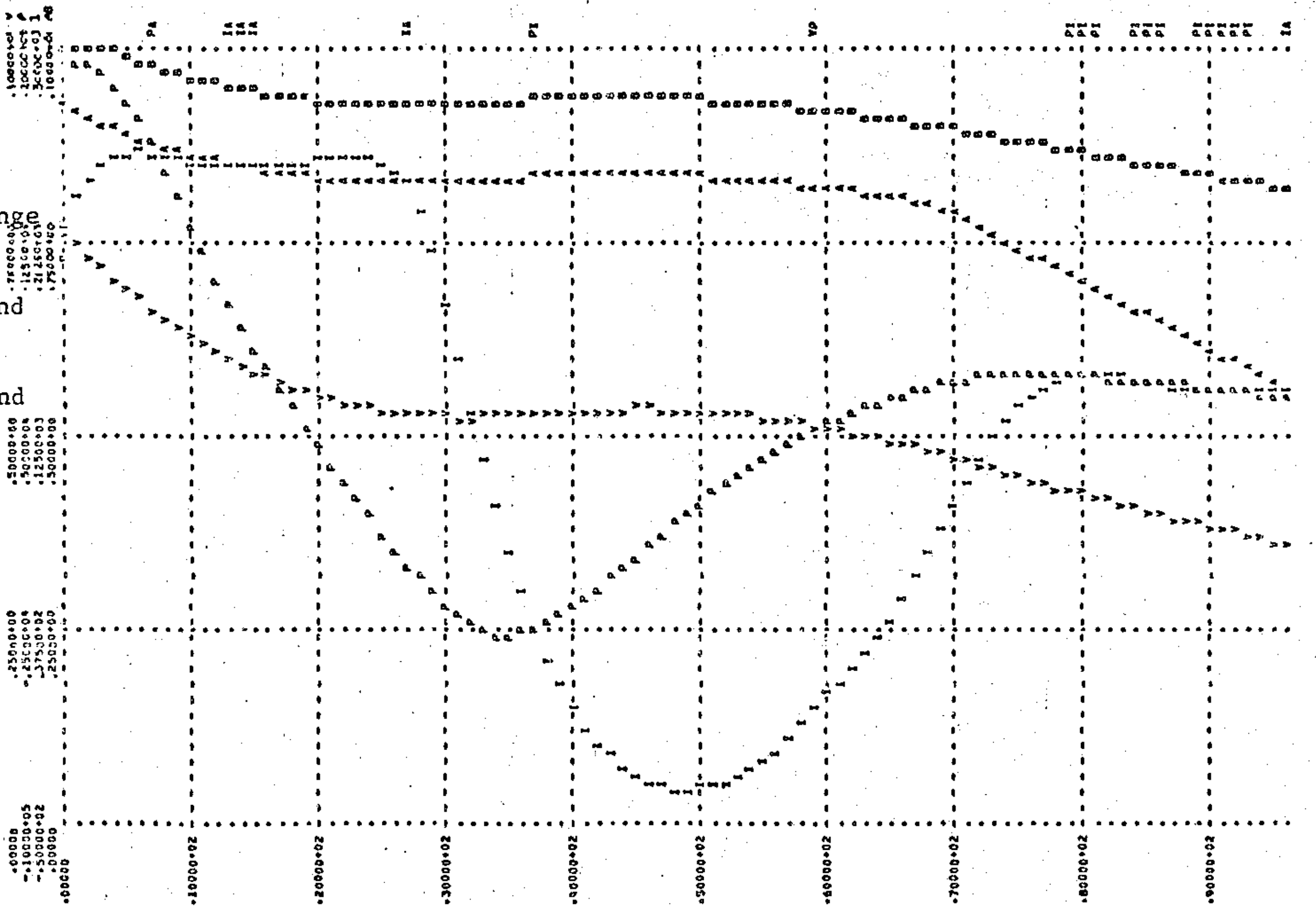


Figure 10. Behavior--DeKalb County Model, Land Sector.

Table 13. Behavior--Land Sector

	1960	1970	1992	2006	2040
Populated Land (L1)	37.5E3	56.9E3	67.7E3	65.3E3	82.5E3
Population Change (LAC)	12.0E3	13.2E3	-.3E3	.7E3	7.3E3
Market Value/Acre Infl. (LAB)	.93	.86	.83	.84	.79
% Vacant Land Infl. (LAF)	.89	.86	.83	.83	.81
Industrial Land (L2)	3.75E3	7.14E3	14.0E3	14.6E5	16.3E3
Industrial Firms Change (LBC)	220	249	136	-31	154
Market Value/Acre Infl. (LBB)	1.00	.96	.93	.94	.87
Percentage Vacant Land (LAG)	.76	.63	.52	.54	.43
Land Use/Person (LAE)	.130	.125	.121	.122	.118

CHAPTER IV

DISCUSSION OF RESULTS

The preceding chapter deals with the behavior of the model presented in Chapter III. This chapter will provide a summary of the important aspects of this behavior. discuss its validity, analyze the assumptions of the model concerning the environment, and briefly tough on the sensitivity of the model with respect to some of its critical parameters.

Summary of Behavior

The simulation begins during a period of extremely rapid growth for DeKalb County. In fact, the most rapid development in the metropolitan area from 1950 to 1960 is occurring in the county. However, this development eventually decreases the relative attractiveness of the county as perceived by potential migrants, and growth begins to occur elsewhere in the metropolitan area at a faster rate than in the county. As the development proceeds in other counties, their perceived relative attractiveness drops, and DeKalb County once again appears a more desirable place in which to live. Table 14 shows characteristics of the county in 1960, 2000, and 2060 and indicates that, in general, the county has deteriorated from 1960 to 2060, even though it is relatively more attractive than other counties in the metropolitan area. In 2060 there is not much vacant land left (35 percent), crowding exists, the per capita income of the county's residents is equal to that of other counties, and the government is approaching its constitutionally imposed debt limit.

Table 14. County Characteristics--1960, 2000, and 2060

Characteristic	1960	2000	2060
Debt (GAU)	42E6	78E6	266E6
Debt (As % Assessed Value) (GAT)	.085	.070	.134
Tax Ratio (GAB)	.73	.87	1.15
Expenses (GB)	39E6	266E6	645E6
Revenues (GA)	34E6	267E6	641E6
Taxes (GAA)	15E6	40E6	96E6
"Other Funds" (GXB)	19E6	227E6	545E6
Population (P1)	257E3	497E3	818E3
Housing Density (PAJ)	.44	.87	1.45
Relative Housing Density (PAM)	1.56	.94	.80
Relative Per Capita Income (PAQ)	1.09	1.02	1.00
Number Commercial Firms (IAF)	2.7E3	10.3E3	14.4E3
Number Manufacutirng Firms (IAN)	175	656	920
Available Jobs (IAS)	64E3	241E3	337E3
Labor Force (IAT)	97E3	193E3	319E3
Populated Land (L1)	37.5E3	65.8E3	92.4E3
Industrial Land (L2)	3.75E3	14.7E3	19.8E3
Percentage Vacant Land (LAG)	.76	.53	.35
Per Capita Land Use (LAE)	.130	.122	.115

The government engaged in deficit spending policies, cannot avoid debt increases during the periods of rapid population growth because of the slowness of the tax loop. When the market value per acre does not increase fast enough to keep the debt to assessed value ratio from increasing, the debt limit is approached.

The behavior mentioned in the preceding paragraph implies a general cycle of development for counties within a metropolitan area. Presumably each of the counties in a metropolitan area will undergo the development process shown by the model to one extent or another. The initial growth phase of these counties should be "staggered" in time, however, depending on the relative attractiveness of each with respect to the other counties. As the growth phase wanes in the initially developed county, it begins to occur in one of the under-developed counties (to a greater extent than in other under-developed counties). The initially developed county suffers a decline due to its decreased perceived relative attractiveness. As the initial growth phase reaches the last of the under-developed counties, the perceived relative attractiveness of the later-developed counties becomes lower than that of the earlier-developed counties. Thus, a second growth phase ensues in the earlier-developed counties. This behavior is evidenced in the DeKalb County simulation after the year 2004. However, the second growth phase may be influenced by factors not considered in this model, such as the resources of the metropolitan area, for example.

Validity of the Model's Behavior

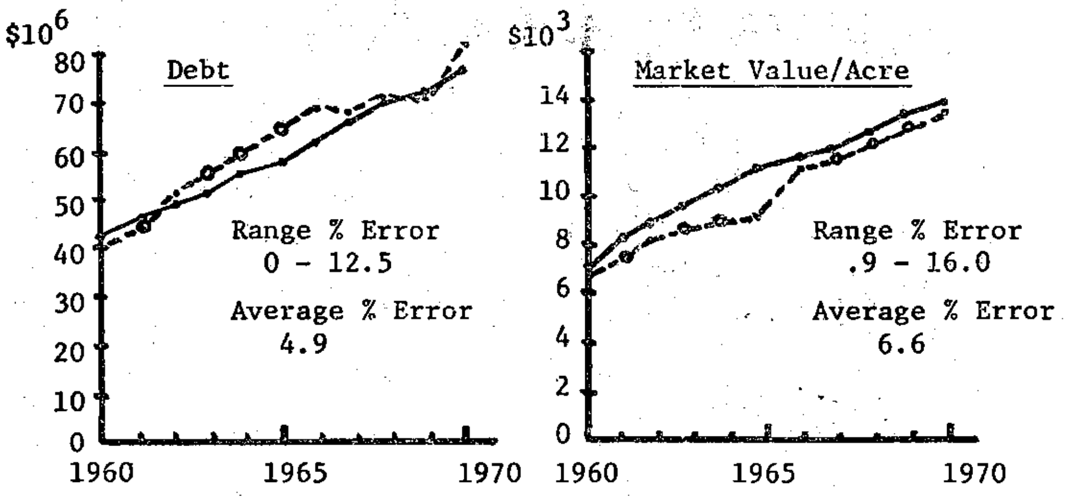
A necessary, but not sufficient, condition which must be met if a model is to be judged valid is that it duplicate the reality which it is supposed to be simulating over a suitable period of time. Table 15 compares the values of the model's most important parameters with their actual values from 1960 to 1970. Figures 11 and 12 display the behavior of these variables graphically. The range and average values of the percentage errors of these variables accompany the figures. The short time span over which this comparison is made is a restriction imposed by the lack of adequate data, especially in the area of government finances. However, for these limited data, the fit appears quite good.

The question to be dealt with when the above condition has been met is ... Does the model duplicate reality for the proper reasons? The answer to this is necessarily general and intuitive. The behavior of this model is consistent with that of the model presented in Urban Dynamics,[14] the primary work in the field, in three respects. First, the county (city) experiences growth and then decline due to a changing perceived relative attractiveness. Secondly, the changes in the relative attractiveness are directly related to housing and social composition of the area under consideration. Finally, the ending state of the area is a deterioration from its initial state. Further comparisons are affected by the different levels of aggregation of the two models, by their respective time frames, and by the system-environment definitions of each. Investigation of the assumptions concerning the environment and the sensitivity of critical parameters shed further light on the question mentioned above.

Table 15. Validation--Model Behavior Versus Reality, 1960-1970

Characteristic	1960		1961		1962		1963		1964		1965		1966		1967		1968		1969		1970		Exponent
	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	
Debt (GAU) 21,22,23,25-30	42	42	47	-	49	56	52	-	57		58	-	62	68	65	67	68	70	72	71	75	79	E6
Market Value/Acre (GAH) 22,23,25-31	7.26	6.90	8.16	-	9.07	8.20	9.71	-	10.34	-	10.95	9.46	11.55	11.40	12.11	-	12.64	-	13.14	-	13.61	13.50	E3
Population (P1) 22,24,32-42	257	257	276	267	296	281	315	292	333	351	317	359	369	329	385	348	400	358	414	370	427	415	E3
Housing Density (PAG) 22,23,32-42	.44	.45	.47	.46	.50	.47	.54	.48	.57	.50	.60	.52	.63	.55	.66	.58	.69	.60	.71	.63	.74	.75	
Relative Per Capita Income (PAG) 22,24-32-42	1.09	1.10	1.09	1.10	1.08	1.10	1.08	1.12	1.08	1.09	1.07	1.09	1.07	1.08	1.07	1.12	1.06	-	1.06	-	1.06	1.08	
Number Industrial Firms (I1) 22,24,43-49	2.92	2.92	3.15	-	3.39	-	3.64	-	3.89	3.60	4.14	3.82	4.40	3.93	4.65	4.07	4.90	4.43	5.15	4.78	5.40	5.10	E3
Commercial Firms/Person (IAJ) 22,24,43-49	.107	.105	.107	-	.108	-	.109	-	.110	.112	.111	.112	.112	.112	.113	.109	.115	.116	.117	.120	.119	.122	
Percentage Vacant Land (LAG 50,51	.76	.76	.75	-	.73	-	.72	-	.70	-	.69	-	.68	-	.66	-	.65	-	.64	-	.63	.66	

Government Sector



Note: ▬ : Model Behavior

--- : Actual Behavior

o : No Data Point

Industrial Sector

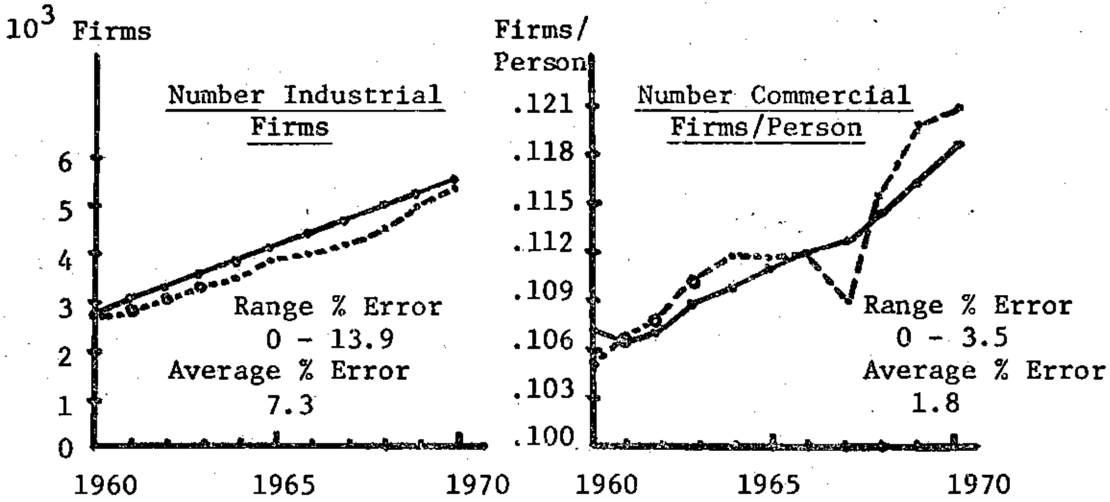
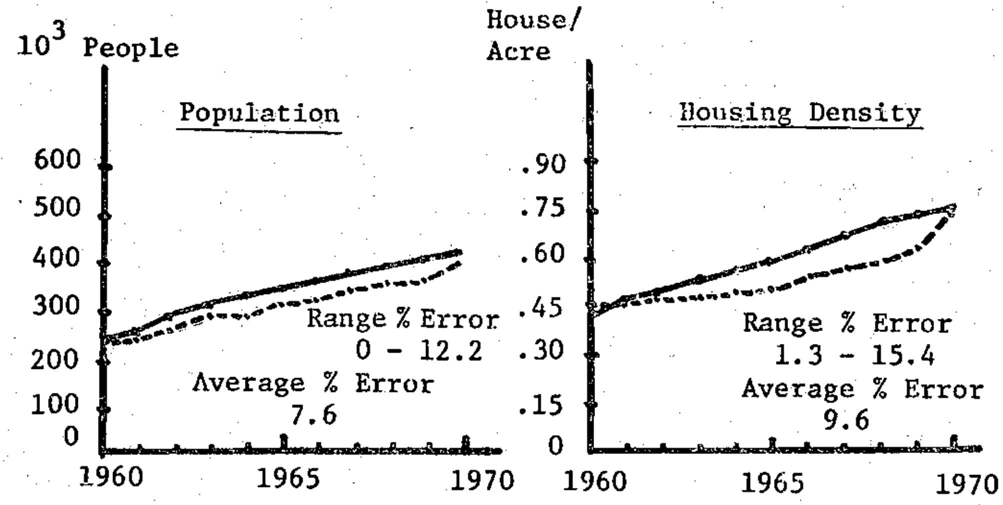


Figure 11. Validation--Model Behavior Versus Reality 1960-1970.

Population Sector



Land Sector

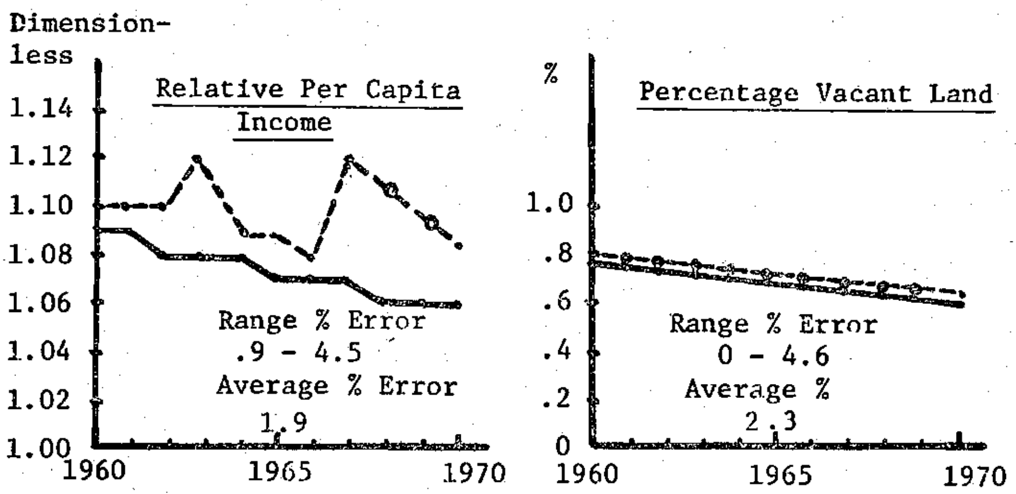


Figure 12. Validation--Model Behavior Versus Reality 1960-1970.

Environmental Assumptions

As stated in the analysis of the model's behavior in Chapter IV, the assumptions concerning the environment have an impact on the model's behavior. Of special interest is the assumption about the yearly rate of population change of the metropolitan area (with its implied increasing housing density). Table 16 displays variations of this assumption for the metropolitan area. Note that the land area is fixed in one case and non-fixed in the other. In the year 2000 the high, "standard run," and low projections of the population of the metropolitan are 3.3, 2.6, and 2.1 million people, respectively.

It is seen in Table 16 that the variation of the assumed yearly rate of change of the population of the metropolitan area has little effect on the behavior of the model in the early stages of the simulation. The magnitudes of the important variables are relatively unaffected, and the timing of the behavior varies at most eight years between variations. However, both the timing and magnitudes of these variables are affected in the later part of the simulation. Note that the final population of the county may vary from 470,000 to 1,130,000 people, depending on the assumption. Varying the assumption of a fixed land area has no effect on the early part of the simulation, but does result in a lower final population level in the county.

Sensitivity of Critical Parameters

The model presented in this thesis is a modification of an earlier formulation, the modification resulting from a comprehensive sensitivity analysis. Several weaknesses were revealed in the analysis; notably

Table 16. Behavior--Varying Environmental Assumptions

Variation	Population					
	Peak		Min.		Final	
	Mag.	Time	Mag.	Time	Mag.	Time
Standard Run	5.2E5	1987	4.9E5	2004	8.2E5	2060
% Change S.M.S.A. (Fixed Area)						
High	5.2E5	1984	5.0E5	2000	11.3E5	2060
Low	5.2E5	1992	4.7E5	2033	4.7E5	2060
% Change S.M.S.A. (Non-Fixed Area)						
High	5.2E5	1984	5.2E5	1990	7.2E5	2060
Standard Run	5.2E5	1986	5.0E5	2004	5.5E5	2060
Low (Same as Fixed)						

1) the limits of several "TABHL" functions were not consistent with actual data, and 2) the form and components of the county's relative attractiveness were poorly specified. To resolve these problems extensive data gathering was undertaken, and regression analysis of this data was employed to determine more accurately the components of the county's relative attractiveness and to quantify more meaningfully their influences on the relative attractiveness. The regression analysis specified the components of the relative attractiveness, but was unable to quantify their influences meaningfully primarily due to the non-linearities involved. Another technique (described in Appendix III) was used to generate these influences in the form of "TABHL" functions. Table 17 shows the effects of varying these "TABHL" functions as well as the perception time of potential migrants with respect to the county's relative attractiveness.

As can be seen in Table 17, the model is relatively insensitive to changes in the perception time of potential migrants with respect to the county's relative attractiveness. However, its behavior is sensitive to changes in any of the "TABHL" functions shown, both in the magnitude and timing. This sensitivity is due to the high state of aggregation of the model which necessitates representing rates and accumulations as "TABHL" functions. As mentioned above, care has been taken in the generation of these "TABHL" functions to insure as much accuracy as possible. In addition, the manner in which these particular functions were generated would reduce any error introduced into any one. It is interesting to note, moreover, that the general mode of behavior is the same in each case. There are two growth phases separated by a period of decline.

Table 17. Behavior--Varying Critical Parameters

	Population					
	Peak		Min.		Final	
Variation	Mag.	Time	Mag.	Time	Mag.	Time
Standard Run	5.2E5	1987	4.9E5	2004	8.2E5	2060
Population Perception Time						
5 Years	4.4E5	1987	4.8E5	2004	8.3E5	2060
15 Years	6.2E5	1988	5.4E5	2006	7.9E5	2060
"TABHL" Functions						
Absolute Housing Density						
High	10.7E5	2005	10.6E5	2022	12.3E5	2060
Low	3.8E5	1972	2.9E5	2000	3.8E5	2060
Relative Housing Density						
High	4.4E5	1970	4.2E5	1975	10.2E5	2060
Low	3.7E5	1971	2.9E5	1997	3.5E5	2060
Relative Per Capita Income						
High	16.8E5	2030	16.7E5	2040	17.5E5	2060
Low	3.6E5	1970	2.6E5	1994	3.5E5	2060

CHAPTER V

CONCLUSIONS

As mentioned in Chapter I, the objective of this thesis is to understand why the problems associated with urban development occur. Specifically, it is desired to know why population and industrial growth occur, how they are related, how land use is affected by their growth, and how the government's finances are impacted. The model presented in this thesis is intended to serve as the basis for development of a comprehensive model of the county which can be used as both a planning aid and policy-evaluating tool.

The model shows that the application of the basic concept of relative attractiveness as described in Urban Dynamics[14] provides a means of examining the forces contributing to urban development. Potential migrants respond to the county's relative attractiveness by either moving into or out of the county. Those components of relative attractiveness which are most influential in this movement are the county's housing and social composition. Industrial firms respond to the movement of people as the population's need for industry changes. Land use varies directly with changes in population and the number of industrial firms. The government's financial condition is stable as long as rapid growth occurs.

The DeKalb County model contributes to existing knowledge of urban development in three ways. First, it presents a county's pattern of development which may be generalized to imply a cycle of development for metropolitan areas. Second, it shows that a county government committed to deficit spending must also be committed to growth, for if the market value of property fails to increase rapidly enough due to decreased growth, a crisis situation develops. Third, the techniques used in determining parameter values (see Appendix III) are specified more precisely than typical work in the field (specifically references 14, 15, 16, and 17) and may be used as a basis for further research.

The model's behavior is accurate for the period 1960 to 1970. However, it may not be used as a general policy-evaluating tool due to deficiencies in its scope and its sensitivity to changes in critical parameters. The model focuses on the explanation of forces causing urban development, rather than on the prediction of the county's future. As such, the model can serve as the base for development of a more comprehensive model, and such expansion would be appropriate.

CHAPTER VI

RECOMMENDATIONS

As suggested in earlier chapters, an expansion of the model would be appropriate. It is felt that a model of the metropolitan area would be of value in several ways. First, it would answer questions related to the cycle of development of a metropolitan area described in Chapter V. Secondly, it could be used to predict where growth would occur, which is a move toward the "spatial" models mentioned in Chapter I. Thirdly, it would allow the direct specification of rates and accumulations aggregated in "TABHL" functions in the present model, which should substantially reduce sensitivity.

The question of sensitivity is directly related to the means by which "TABHL" functions are formulated and generated. The problem is two-fold; the first step is determining which variable has significant influence on another, the second step is determining the shape and magnitude of the influence. This thesis has attempted to use regression analysis for the first step and a modified interval averaging for the second step, both with what is felt is only partial success. It seems that this is a rich area for research, and any increase in knowledge which leads to a more meaningful technique for determining these functions would be of great value in this type of sociological modeling.

APPENDICES

APPENDIX I

The Model

This appendix describes the model used in this thesis to represent DeKalb County, Georgia. The model is stated in mathematical equations which are specific and precise. Each equation will be described, and a compact listing of the equations is given in Appendix II.

Government Sector

Equation 1 is the accumulation equation describing the government's "cash balance." It states that at a given point in time the government's "cash balance" is the sum of its balance at the end of the previous year and the difference between its revenues and expenses during during the year. Note that "DT" is the time interval between computations during the simulation and in this case is one year. The initial value of the "cash balance" is -42.4 million dollars.

$$G1.K = G1.J + (DT)(GA, JK - GB, JK) \qquad (1,1L)$$

$$G1 = -42.4E6 \qquad (1.1,6N)$$

GA = Government "Cash Balance"

GB = Expense Rate

The government's revenue rate (dollars/year) is given by Equation 2. As seen, it is the sum of two variables which represent two distinct sources of funds. One is the property taxes collected each year, the other is "other funds" which is a combination of service fees, license fees, and transfer funds received each year.

$$GA.KL = GAA.K + GXB.K \qquad (2,7R)$$

GA = Revenue Rate

GAA = Taxes Collected

GXB = "Other Funds"

Equation 3 shows that the "taxes collected" is the product of three terms. One term is the assessed value of all taxable property in the county, the other two represent the actual millage rate of the county. The actual millage rate is the product of the "normal" millage rate of governmental units in the Atlanta metropolitan area and a multiplier reflecting the tax needs of the county modified by the influence of political pressure associated with tax increases.

$$GAA.K = (GADA)(GAB.K)(GAF.K) \qquad (3,13A)$$

GAA = Taxes Collected

GADA = Normal Millage Rate

GAB = Tax Ratio

GAF = Assessed Value--Property

The multiplier mentioned in Equation 3's description is the ratio of the county's millage rate to the normal millage rate. It is represented by Equation 4 and is based on the tax ratio which is perceived by the government as being needed. This relationship recognizes the political pressures associated with tax increases.

$$GAB.K = TABHL\ (GABT,\ GAC.K,\ .5,\ 5,\ .5) \qquad (4,58A)$$

GABT* = .6/1/1.4/1.8/2,2/2.5/2.8/3/3.2/3.4 (4.1,C)

GAB = Tax Ratio

GABA = Tax Ratio Table

GAC = Tax Ratio Needed--Perceived

As stated above, the tax ratio is based on the tax ratio needed as perceived by the government. It is an accumulation equation, but actually combines within itself a rate equation which causes the accumulation to change. The perceived tax ratio needed is always moving toward the true tax need. The rate at which it moves depends on the difference between the true and perceived tax ratio needed of the previous period. The difference is divided by the perception time of the government to create the rate of change in the perceived tax ratio needed. The basic relationships of this equation are true of all perceived variables in the model. The value of the tax ratio needed--perceived in 1960 is set at .61.

GAC.K = GAC.J + (DT)(1/GACD)(GAD.J-GAC.J) (5,3L)

GAC = .61 (5.1,6N)

GACD = 5 (5.2,C)

GAC = Tax Ratio Needed--Perceived

GACD = Perception Time--Tax Ratio Needed

GAD = Tax Ratio Needed

Equation 6 gives the representation of the true tax ratio needed. It is the ratio of the millage needed to the normal millage rate of governmental units in the Atlanta metropolitan area.

$$GAD.K = GAE.K/GADA \qquad (6,20A)$$

$$GADA = .0418 \qquad (6.1,C)$$

GAD = Tax Ratio Needed

GADA = Normal Millage Rate

GAE = Millage Needed

Equation 7 describes the millage rate needed as being the ratio of the property taxes needed to the assessed value of taxable property.

$$GAE.K = GAK.K/GAF.K \qquad (7,20A)$$

GAE = Millage Needed

GAK = Taxes Needed

GAF = Assessed Value--Property

The assessed value of taxable property in the county is stated in Equation 8 to be 40 percent of the market value of the property. The State government has specified the 40 percent value, and the county's tax assessors determine the market value of the county's property. "Property" is defined as all real property, not just land alone.

$$GAF.K = (.4)(GAG.K) \qquad (8,12A)$$

GAF = Assessed Value--Property

GAG = Market Value--Property

The market value of property in the county is given by Equation 9 as the product of the market value of property per acre and the total land area of the county.

GAG.K = (LAGA)(GAH.K) (9,12A)

GAG = Market Value--Property

LAGA = Total Land Area--County

GAH = Market Value/Acre

Equation 10 shows the market value per acre of property in the county to be the product of three variables. These are the housing density of the county, the housing density's influence on the market value per acre, and a scaling factor.

GAH.K = (PAJ.K)(GAJ.K)(GAHA) (10,13A)

GAHA = 1E4 (10.1,C)

GAH = Market Value/Acre

GAHA = Scaling Factor

PAJ = Housing Density

GAJ = Housing Density's Influence on Market Value/Acre

Equation 11 is the "TABHL" function describing the housing density of the county's influence on its market value per acre. It shows that as the housing density increases, the market value per acre increases, at a decreasing rate.

GAJ.K = TABHL (GAJT, PAJ.K, .25, 3, .25) (11.58A)

GAJT* = 1.25/1.8/1.85/1.9/1.95/2/2.05/2.1/2.15/2.2/2.25/2.3 (11.1,C)

GAJ = Housing Density's Influence on
Market Value/Acre

GAJT = Housing Density's Influence--Table

PAJ = Housing Density

The property taxes needed are the difference between projected expenses and projected "other funds." This represents the comparison of the projected county budget with projected revenues other than taxes, the difference being the property taxes needed. Equation 12 gives the relationship.

$$GAK.K = GAV.K-GAL.K \qquad (12,7A)$$

GAK = Taxes Needed

GAL = Projected "Other Funds"

GAV = Perjected Expenses

Equation 13 shows the projected "other funds" to be the product of the projected population of the county for the next year and the current per capita "other funds." The current per capita "other funds" are the product of the environmental per capita "other funds" and the influence of the county's debt position (as reflected by its debt limit comparison) on its ability to raise funds via "other funds." This formulation is selected due to the large transfer of funds to the County School Board by the State government on essentially a per capita basis and due to the per capita nature of service fees.

$$GAL.K = (GAM.K)(GAN.K)(GAR.K) \qquad (13,13A)$$

GAL = Projected "Other Funds"

GAM = Environmental Per Capita "Other Funds"

GAN = Projected Population

GAR = Debt Limit Comparison's Influence on "Other Funds"

The environmental per capita "other funds" are given by Equation 14 and are a function of time. This representation is used to allow testing of assumptions of future behavior of per capita "other funds." It is similar to three other variables which characterize the state of the Atlanta metropolitan area over the course of the simulation. The per capita "other funds" are time-dependent due to their heavy dependence on factors external to the county, namely the whims of the State legislature. Equation 14 shows this time-dependence.

GAM.K = TABHL (GAMT, TIME.1C, 0, 100, 10) (14,58A)

GAMT* = 70/140/252/373/445/464/482/500/520/540/560 (14.1,C)

GAM = Environmental Per Capita "Other Funds"

GAMT = Environmental Per Capita "Other Funds"--Table

The projected population of the county for the next year is given by Equation 15 to be the current year's population plus the projected population growth in the coming year, multiplied by the projection time.

GAN.K = P1.K + (GAND)(GAP.K) (15,14A)

GAND = 1 (15.1,C)

GAN = Projected Population

GAND = Projection Time

GAP = Projected Growth in Population

P1 = Population

The projected growth in population is shown by Equation 16 to be the difference between the actual and perceived populations divided by the government's perception time with respect to the population.

GAP.K = (1/GAQD)(P1.K-GAQ.K) (16,21A)

GAP = Projected Growth in Population

GAQ = Perceived Population

GAQD = Perception Time--Population

P1 = Population

Equation 17 describes the perceived population. It is similar in form to the tax ratio needed--perceived mentioned previously in Equation 5. It states that the perceived population is the sum of last year's perceived population and the difference between last year's actual and perceived populations divided by the government's perception time with respect to the population.

GAW.K = GAQ.J + (DT)(1/GAQD)(P1.J-GAQ.J) (17,3L)

GAQ = 1.97E5 (17.1,6N)

GAQD = 5 (17.2,C)

GAQ = Perceived Population

GAQD = Perception Time--Population

P1 = Population

The influence of the government's debt limit comparison on "other funds" is depicted in Equation 18. The equation shows that, as the comparison decreases, its influence on revenues via "other funds" increases until it becomes constant. This function is used to represent service fee increases which eventually reach a limit.

GAR.K = TABHL (GART, GAS.K, -.1, .1, .02) (18,58A)

GART* = 1.2/1.2/1.2/1.2/1.2/1.2/1.15/1.1/1.05/1/1 (18.1C)

GAR = Debt Limit Comparison's Influence on "Other Funds"

GART = Debt Limit Comparison's Influence--Table

GAS = Debt Limit Comparison

The government's debt limit comparison is the difference between its actual debt to assessed value ratio and its constitutionally-imposed limit of 14 percent. Equation 19 shows this.

GAS.K = .14 - GAT.K (19,7A)

GAS = Debt Limit Comparison

GAT = Debt to Assessed Value Ratio

Equation 20 states that the government's debt to assessed value ratio is its debt divided by its assessed value of taxable property.

GAT.K = GAU.K/GAF.K (20,20A)

GAT = Debt to Assessed Value Ratio

GAU = Debt--Government

GAF = Assessed Value--Property

The government's debt is its cash balance multiplied by -1. Equation 21 shows this.

$$GAU.K = (-1)(G1.K) \qquad (21,12A)$$

GAU = Debt--Government

G1 = Government Cash Balance

Equation 22 describes the projected expenses of the government for the next year. They are the product of the projected population and the projected per capita expenses for the next year. Note that the projected expenses differ from the projected "other funds" in that per capita "other funds" are not projected. This is intended to represent a conservative fiscal policy; that of assuming per capita expenses will increase, and conservatively estimating per capita "other funds" to remain constant due to their dependence on external factors. A per capita formulation is used because of the reliance of budget projections on projected population growth in the county.

$$GAV.K = (GAN.K)(GAW.K) \qquad (22,12A)$$

GAV = Projected Expenses

GAN = Projected Population

GAW = Projected Per Capita Expenses

Projected Per Capita Expenses are given in Equation 23 as the sum of the current per capita expenses and the projected growth in per capita expenses, multiplied by the projection time.

$$GAW.K = GXA.K + (GAWD)(GAY.K) \qquad (23,14A)$$

$$GAWD = 1 \qquad (23.1,C)$$

GAW = Projected Per Capita Expenses

GAWD = Projected Time--Per Capita Expenses

GAY = Projected Growth--Per Capita Expense

GXA = Per Capita Expenses

The growth in per capita expenses is represented by Equation 24. It is the difference between the actual and perceived per capita expenses divided by the government's perception time with respect to per capita expenses.

GAY.K = (1/GAZD)(GXA.K-GAZ.K) (24,21A)

GAY = Growth in Per Capita Expenses

GAZ = Perceived Per Capita Expenses

GAZD = Perception Time--Per Capita Expenses

GXA = Per Capita Expenses

Equation 25 expresses the relationships involved with the perceived per capita expenses. They are similar to the "perceived" variables mentioned previously in Equations 5 and 17. The perceived per capita expenses are the sum of last year's perceived per capita expenses and the difference between last year's actual and perceived per capita expenses. The initial value of the perceived per capita expense is $132 per person per year.

GAZ.K = GAZ.J + (DT)(1/GAZD)(GXAJ-GAZ.J) (25,3L)

GAZ = 132 (25.1,6N)

GAZD = 2 (25.2,C)

GAZ = Perceived Per Capita Expenses

GAZD = Perception Time--Per Capita Expenses

GXA = Per Capita Expenses

The actual per capita expenses are the government's expense rate divided by last year's population. Equation 26 shows this.

$$GXA.K = GB.JK/LAD.K \qquad (26,20A)$$

GXA = Per Capita Expenses

GB = Expense Rate

LAD = Last Year's Population

The "other funds" received by the government each year are decribed by Equation 27. They are the product of the environmental per capita "other funds," the county's population, and the influence of the government's debt limit comparison on "other funds."

$$GXB.K = (GAM.K)(P1.K)(GAR.K) \qquad (27,13A)$$

GXB = "Other Funds"

GAM = Environmental Per Capita "Other Funds"

GAR = Debt Limit Comparison's Influence on "Other Funds"

P1 = Population

The government's expense rate is similar in form to its "other funds." Equation 28 shows the expense rate to be the product of the county's population, the environmental per capita expenses, and the influence of the government's debt limit comparison on expenses. The expense rate includes both capital and operational expenditures.

$$GB.KL = (GBA.K)(GBB.K)(P1.K) \qquad (28,13R)$$

GB = Expense Rate

GBA = Environmental Per Capita Expenses

GBB = Debt Limit Comparison's Influence on Expenses

P1 = Population

Equation 29 displays the time-dependent environmental per capita expenses, which is similar in form to the representation of environmental per capita "other funds" of Equation 14. The environmental per capita expense increases over the course of the simulation, and from the year 2000 at a rate greater than that of the environmental per capita "other funds." This positive "net" of environmental per capita expenses and other funds exerts a positive influence on the taxes needed.

GBA.K = TABHL (GBAT, TIME.K, 0, 100, 10) (29,58A)

GBAT* = 169/270/400/516/578/636/700/770/847/932/1025 (29.1,C)

GBA = Environmental Per Capita Expenses

GBAT = Environmental Per Capita Expenses--Table

The influence of the government's debt limit comparison on its expense rate is given by Equation 30. It shows that as the comparison decreases, the expense rate decreases. The influence represents capital expenditures due to the government's inability to float bond issues and sell them to potential investors.

GBB.K = TABHL (GBAT, GAS.K, -.1, .1, .02) (30,58A)

GBBT* = .65/.65/.65/.65/.65/.75/.8/.85/.9/.95/1 (30.1,C)

GBB = Debt Limit Comparison's Influence on Expenses

GBBT = Debt Limit Comparison's Influence on Expenses--Table

GAS = Debt Limit Comparison

Population Sector

The accumulation equation for the county's population is Equation 31. It states that each year the county's population is altered by the net rate of change in population per year. The county's population in 1960 is 257,000 people.

P1.K = P1.J + (DT)(PA.JK + 0) (31,1L)

P1 = 257E3 (31.1,6N)

P1 = Population

PA = Net Yearly Change in Population

Equation 32 describes the net rate of change in the county's population per year. It is the product of three terms, the first of which is the population of the county. The second is the environmental percentage change in population per year. It is initially three percent and gradually declines over the course of the simulation. The third term is a modulating term representing the perceived attractiveness of the county relative to the environment. The normal value of the perceived relative attractiveness is one. A more attractive area will have a perceived relative attractiveness greater than one; a less attractive area will have one less than one. As the county becomes more or less attractive than the envirionment, the perceived relative attractiveness changes.

PA.KL = (P1.K)(PAA.K)(PAD.K) (32,13R)

PA = Net Yearly Change in Population

P1 = Population

PAA = Perceived Relative Attractiveness

PAD = Environmental Yearly Percentage Change in Population

The county's perceived relative attractiveness is represented in Equation 33. It is similar in form to those "perceived" variables described earlier. This equation creates a time delay representing the time for the image of the county to change in the minds of those who might migrate into it. This delay in perception is 10 years and is shorter than the similar delay in Urban Dynamics.[14] This is due to the assumption that persons migrate initially to the Atlanta metropolitan area, then to DeKalb County. As such, all migration in this model is treated as intrametropolitan migration, which possesses a shorter perception time delay than that of intermetropolitan migration. The initial value of the county's perceived relative attractiveness is 2.50.

$$PAA.K = PAA.J + (DT)(1/PAAD)(PAB.J-PAA.J) \qquad (33,3L)$$

$$PAA = 2.50 \qquad (33.1,6N)$$

$$PAAD = 10 \qquad (33.2,C)$$

PAA = Perceived Relative Attractiveness

PAAD = Perception Time--Relative Attractiveness

PAB = Scaled Relative Attractiveness

The county's scaled relative attractiveness is its actual relative attractiveness modified by the influence of the changing yearly percentage change in population of the environment. In the formulation of relative attractiveness in this model, it is necessary to have a measure which can be both positive and negative (to indicate growth and decay). The ratio of the yearly percentage change of population in the county to the yearly percentage change of population in the environment was selected as such a measure. However, as the yearly change of population in the environment changes, the base of comparison changes. The influence multiplier mentioned above accounts for this. Equation 34 depicts the scaled relative attractiveness.

PAB.K = (PAC.K)(PAE.K) (34,12A)

PAB = Scaled Relative Attractiveness

PAC = Environmental Yearly Percentage Change's Influence on the Actual Relative Attractiveness

PAE = Actual Relative Attractiveness

Equation 35 given the environmental yearly percentage change's influence on the actual relative attractiveness. As shown, as the percentage change increases, the influence decreases.

PAC.K = TABHL (PACT, PAD.K, .005, .03, .005) (35,58A)

PACT* = 5.85/2.94/1.97/1.48/1.23/1 (35.1,C)

PAC = Environmental Yearly Percentage Change's Influence on the Relative Attractiveness

PACT = Yearly Percentage Change's Influence--Table

PAD = Environmental Yearly Percentage Change in Population

The time dependent environmental yearly percentage change in population is given by Equation 36. It shows that the percentage change in population is initially three percent per year and gradually declines over the course of the simulation.

```
PAD.K = TABHL (PADT, TIME.K, 0, 100, 10)            (36,58A)

PADT* = .03/.0275/.025/.0225/.02/.0175/             (36.1,C)
        .0.5/.0125/.01/.0075/.005

  PAD = Environmental Yearly Percentage
        Change in Population

 PADT = Yearly Percentage CHange in Population--
        Table
```

As discussed in the description of Equation 34, it was desirable to have a measure of relative attractiveness which can be both positive and negative. It was stated that the ratio of the yearly percentage change of population in the county to the yearly percentage change of population in the environment was selected as the measure. However, this measure was unwiedly in the generation of "TABHL" function, and another related measure was used. The other measure is the ratio of the ratio of "absolute" population change in the county to the "absolute" population change in the environment, where "absolute" population change is defined as the ratio of the current population to last year's population. Note that this measure is positive only, and a conversion table is needed between the two measures. Equation 37 provides such a table.

```
PAE.K = TABHL (PAET, PAF.K, .91, 1.09, .02)         (37,58A)

PAET* = -2/-1.33/-.67/0/.67/1.33/2/2.67/            (37.1,C)
        3.33/4
```

PAE = Actual Relative Attractiveness

PAET = Actual Relative Attractiveness--Table

PAF = Relative Attractiveness

Equation 38 describes the county's relative attractiveness. It is a combination of four factors; the influence of the absolute housing density, the influence of the relative per capita income, and an adjustment to the changing environmental yearly percentage change in population similar to that described in Equation 34. Note that the housing densities' and relative per capita income's influences are equally weighted.

PAF.K = (PAH.K)(PAL.K)(.5) + (PAP.K)(1)(.5) + (PAG.K)(1)(1) (38,17A)

PAF = Relative Attractiveness

PAG = Environmental Yearly Percentage Change's Influence on the Relative Attractiveness

PAH = Absolute Housing Density's Influence on Relative Attractiveness

PAL = Relative Housing Density's Influence on Relative Attractiveness

PAP = Relative Per Capita Income's Influence on Relative Attractiveness

The influence of the changing environmental yearly percentage change in population on the relative attractiveness of the county is shown in Equation 39. As the environmental yearly percentage change in population increases, its influence on the relative attractiveness decreases.

PAG.K = TABHL (PAGT, PAD.K, .005, .03, .005) (39,58A)

PAGT* = .025/.02/.015/.01/.005/0 (39.1,C)

PAG = Environmental Yearly Percentage Change's Influence on the Relative Attractiveness

PAGT = Yearly Percentage Change's Influence--Table

PAD = Environmental Yearly Percentage CHange in Population

Equation 40 depicts the county's absolute housing density's influence on the relative attractiveness. As the housing density increases, its influence on the relative attractiveness decreases. It should be noted that the influences of the absolute housing density, the relative attractiveness were not determined independently. Therefore, any error in one of the influences produces a compensating error in the other two influences.

PAH.K = TABHL (PAHT, PAJ.K, .2, 2, .2) (40,58A)

PAHT* = .96/.89/.85/.84/.837/.833/.83/ .827/.823/.82 (40.1,C)

PAH = Absolute Housing Density's Influence on Relative Attractiveness

PAHT = Absolute Housing Density's Influence--Table

PAJ = Housing Density

The county's housing density is shown in Equation 41. It is the product of three terms which comprise the total number of houses in the county divided by the total land area of the county. The total number of houses is the normal per capita housing multiplied by the county's population and the influence of the percentage vacant land on per capita housing. It is noted that the normal per capita housing is a composite average based on national figures. It is modified by the land availability in the county to depict the county's per capita housing.

PAJ.K = (P1.K)(PAK.K)(PAJA)/((LAGA)(1)(1)) (41,46A)

PAJA = .32 (41.1,C)

PAJ = Housing Density

PAJA = Normal Per Capita Housing

P1 = Population

PAK = Percentage Vacant Land's Influence on Per Capita Housing

LAGA = Total Land Area County

The influence of the percentage vacant land left in the county on per capita housing is depicted in Equation 42. It shows that as the percentage of vacant land decreases, the per capita housing increases, reflecting changing building patterns as land becomes scarce.

PAK.K = TABHL (PAKT, LAG.K, 0, 1, .2) (42,58A)

PAKT* = 1/.97/.95/.93/.91/.9 (42.1,C)

PAK = Percentage Vacant Land's Influence on Percapita Housing

PAKT = Percentage Vacant Land's Influence

LAG = Percentage Vacant Land

Equation 43 illustrates the influence of the county's relative housing density on the relative attractiveness. When the county's relative housing density decreases, its influence on the relative attractiveness decreases. It should be pointed out that this influence on relative attractiveness is part of the total "housing density" influence.

PAL.K = TABHL (PALT, PAM.K, .2, 2, .2) (43,58A)

PALT* = 1.2/1.175/1.14/1.11/1.07/1.03/ 1.02/1.01/1/.99 (43.1,C)

PAL = Relative Housing Density's Influence on Relative Attractiveness

PALT = Relative Housing Density's Influence--Table

PAM = Relative Housing Density

The county's relative housing density is its housing density divided by the housing density of the environment. It represents the extent of housing availability or crowding existing in the county relative to the environment and is given by Equation 44.

PAM.K = PAJ.K/PAN.K (44,20A)

PAM = Relative Housing Density

PAJ = Housing Density

PAN = Environmental Housing Density

The environmental housing density is another of the time-dependent variables which characterize the Atlanta metropolitan area. It changes directly with the assumption concerning the yearly percentage change of population in the environment and the assumption concerning the land area of the metropolitan area. Equation 45 shows the environmental housing density from 1960 to 2060.

PAN.K = TABHL (PANT, TIME.K, 0, 100, 10) (45,58A)

PANT* = .28/.41/.6/.75/.92/1.1/1.3/1.47/1.61/1.73/1.82 (45.1,C)

PAN = Environmental Housing Density

PANT = Environmental Housing Density--Table

The influence of the relative per capita income on the relative attractiveness is given in Equation 46. As the relative per capita income increases, its influence on the relative attractiveness increases.

PAP.K = TABHL (PAPT, PAQ.K, .8, 1.15, .05) (46,58A)

PAPT* = .88/.93/.96/.98/1/1.1/1.105/1.11 (46.1,C)

PAP = Relative Per Capita Income's Influence on Relative Attractiveness

PAPT = Relative Per Capita Income's Influence--Table

PAQ = Relative Per Capita Income

The county's relative per capita income is shown in Equation 47. It is the product of the county's relative per capita income in the last year and a change multiplier reflecting the influences of the magnitude of the relative per capita income and the county's relative attractiveness.

PAQ.K = (PAR.K)(PAU.K) (47,12A)

PAQ = Relative Per Capita Income

PAR = Change Multiplier

PAU = Last Year's Relative Per Capita Income

The change multiplier mentioned above is the product of the influences of the magnitude of the current relative per capita income and the county's perceived relative attractiveness on the yearly change in the relative per capita income. Equation 48 illustrates this.

PAR.K = (PAS.K)(PAT.K) (48,12A)

PAR = Change Multiplier

PAS = Perceived Relative Attractiveness' influence on the Change in Relative Per Capita Income

PAT = Magnitude of Relative Per Capita Income's Influence on Change in Relative Per Capita Income

The influence of the perceived relative attractiveness on the change in the relative per capita income is shown in Equation 59. It is seen that as the perceived relative attractiveness of the county increases, its influence increases.

PAS.K = TABHL (PAST, PAA.K, -4, 6, 1.67) (49,58A)

PAST* = .99/.9995/1/1/1/1.0034/1.0068 (49.1,C)

PAS = Perceived Relative Attractiveness' Influence on the Change in Relative Per Capita Income

PAST = Perceived Relative Attractiveness' Influence--Table

PAA = Perceived Relative Attractiveness

The influence of the magnitude of the previous year's relative per capita income on the change in it during the year is given in Equation 50. It is seen that as the magnitude of the relative per capita income increases, its tendency to increase decreases.

PAT.K = TABHL (PATT, PAU.K, .85, 1.25, .05) (50,58A)

PATT* = 1/1/1/1/.998/.996/.994/.992/.990 (50.1,C)

PAT = Magnitude of Relative Per Capita Income's Influence on the Change in the Relative Per Capita Income

PATT = Magnitude of Relative Per Capita Income's Influence--Table

PAU = Last Year's Relative Per Capita Income

Equation 51 displays last year's relative per capita income as an "averaging" equation with an averaging time of one year. This equation is similar in form to those of the "perceived" variables mentioned before and functions in the same manner. Its initial value is 1.096.

PAU.K = PAU.J + (DT)(1/PAUD)(PAQ.J-PAU.J) (51,3L)

PAU = 1.096 (51.1,6N)

PAUD = 1 (51.2,C)

PAU = Last Year's Relative Per Capita Income

PAUD = Averaging Time--Relative Per Capita Income

PAQ = Relative Per Capita Income

Industrial Sector

The number of industrial firms in the county is given by the accumulation Equation 52. In 1960 there are 2,920 industrial firms in the county. Industrial firms is defined as both manufacturing and commercial firms.

$$I1.K = I1.J + (DT)(IA.JK + 0) \qquad (52,1L)$$

$$I1 = 2.92E3 \qquad (52.1,6N)$$

I1 = Industrial Firms

IA = Net Yearly Rate of Change of Industrial Firms

Equation 53 shows the net yearly rate of change of industrial firms in the county to be the product of the current number of industrial firms and the "delayed" yearly percentage rate of change in industrial firms.

$$IA.KL = (I1.K)(IAA.K) \qquad (53,12R)$$

IA = Net Yearly Change in Industrial Firms

I1 = Industrial Firms

IAA = "Delayed" Yearly Percentage Rate of Change of Industrial Firms

The "delayed" yearly percentage rate of change of industrial firms is analogous to the product of the perceived relative attractiveness and the environmental yearly percentage change in population of the population sector. It is a direct formulation for yearly percentage change. The delay time of five years represents the time it takes for a "typical" industrial firm to formulate and implement a location decision. Equation 54 describes this delayed percentage change.

IAA.K = IAA.J + (DT) (1/IAAD)(IAB.J-IAA.J) (54,3L)

IAA = .08 (54.1,6N)

IAAD = 5 (54.2,C)

IAA = "Delayed" Yearly Percentage Rate of Change of Industrial Firms

IAAD = Delay Time--Yearly Percentage Rate of Change

IAB = Yearly Percentage Rate of Change of Industrial Firms

The yearly percentage rate of change of industrial firms is shown in Equation 55. It is the sum of the influences of the "total" need for industry and the "total" labor situation, which are expressed in terms of percentage change per year.

IAB.K = IAC.K + IAK.K (55,7A)

IAB = Yearly Percentage Rate of Change of Industrial Firms

IAC = Total Need for Industry's Influence on Percentage Change

IAK = Total Labor Situation's Influence on Percentage Change

Equation 56 shows that the total need for industry influence on the yearly percentage rate of change of industrial firms is the product of two terms. One depicts the effects of competition as reflected by the number of commercial firms in the county. The other represents the influence of the county's need for industry.

$$IAC.K = (IAD.K)(IAG.K) \qquad (56,12A)$$

IAC = Total Need for Industry's Influence on Percentage Change

IAD = Number of Commercial Firms' Influence on the Total Need

IAG = Need for Industry's Influence on the Total Need

The influence of the number of commercial firms in the county on the total need for industry is intended to reflect the effects of competition. As the number of commercial firms in the county increases, the total need for industry decreases. Note, however, that the influence begins to increase when the number of commercial firms reaches 12,000. This is not to imply that more firms enter the county due to this influence. Rather this "TABHL" function must be considered in conjunction with the need for industry influence. When these "TABHL" functions were generated, it was assumed that when the level of commercial firms reaches 12,000, the need for industry should exert a negative influence on the total need. Thus, the increasing influence of the number of commercial firms would produce an increasing negative influence on the total need. Therefore, the total need influence is a monotonically decreasing influence. Equation 57 shows the influence of the number of commercial firms on the total need for industry.

$$IAD.K = TABHL\ (IADT, IAE.K,\ 2,\ 16,\ 2) \qquad (57,58A)$$

IADT* = 3.5/1.8/1.3/1.2/1.1/1/1.7/2.5 (57.1,C)

IAD = Number of Commercial Firm's Influence on the Total Need

IADT = Number of Commercial Firm's Influence--Table

IAE = Scaled Number of Commercial Firms

Equation 58 presents the scaled number of commercial firms as the number of commercial firms in the county divided by 1000.

IAE.K = (IAF.K)(IAEA) (58,12A)

IAEA = 1E-3 (58.1,C)

IAE = Scaled Number of Commercial Firms

IAEA = Scaling Factor

IAF = Number of Commercial Firms

The number of commercial firms in the county is the number of industrial firms in the county multiplied by the normal fraction of industrial firms which are commercial firms. The normal fraction is 94 percent and is a composite average based on national data. Equation 59 shows the representation.

IAF.K = (I1.K)(IAFA) (59,12A)

IAFA = .94 (59.1,C)

IAF = Number of Commercial Firms

IAFA = Normal Fraction--Commercial Firms

I1 = Industrial Firms

Equation 60 displays the need for industry's influence on the total need for industry. It shows that as the county's need for industry increases, its influence on the total need increases. The county's need for industry is defined as its per capita commercial firms subtracted from the normal per capita commercial firms. As can be seen, the total need for industry is solely a function of the commercial firms in the county and is not related to manufacturing firms.

IAG.K = TABHL (IAGT, IAH.K, -.006, .008, .002) (60,58A)

IAGT* = -.013/-.007/-.003/.002/.011/.016/.018/.019 (60.1,C)

IAG = Need for Industry's Influence on on the Total Need

IAGT = Need for Industry's Influence--Table

IAH = Need for Industry

As mentioned above, the county's need for industry is the difference between its per capita commercial firms and the normal per capita commercial firms which is a composite average of data from 90 representative counties. Equation 61 gives this formulation.

IAH.K = IAHA - IAJ.K (61,7A)

IAHA = .018 (61.1,C)

IAH = Need for Industry

IAHA = Normal Per Capita Commercial Firms

IAJ = Per Capita Commercial Firms

The county's per capita commercial firms is described by Equation 62. It is the number of commercial firms in the county divided by the county's population.

$$IAJ.K = IAF.K/P1.K \qquad (62,20A)$$

IAJ = Per Capita Commercial Firms

IAF = Number of Commercial Firms

P1 = Population

The total labor situation's influence on the county's yearly percentage rate of change of industrial firms is depicted in Equation 63. It is similar in form to the total need for industry's influence and is the product of the number of manufacturing firms' influence and the labor situation's influence. Note that it is dependent on manufacturing firms only.

$$IAK.K = (IAL.K)(IAP.K) \qquad (63,12A)$$

IAK = Total Labor Situation's Influence on the Percentage Change

IAL = Number of Manufacturing Firms' Influence on the Total Labor Situation

IAP = Labor Situation's Influence on the Total Labor Situation

Equation 64 gives the influence of the number of manufacturing firms on the total labor situation. It is similar to the number of commercial firms' influence of Equation 57 and functions in conjunction with the labor situation's influence to produce a monotonically decreasing function.

IAL.K = TABHL (IALT, IAM.K, 0, 1.5, .5) (64,58A)

IALT* = 7.8/5.5/1/3.9 (64.1,C)

IAL = Number of Manufacturing Firm's Influence on the Total Labor Situation

IALT = Number of Manufacturing Firms' Influence--Table

IAM = Scaled Number of Manufacturing Firms

The scaled number of manufacturing firms is the number of manufacturing firms in the county divided by 1000. Equation 65 shows this.

IAM.K = (IAN.K)(IAEA) (65,12A)

IAM = Scaled Number of Manufacturing Firms

IAEA = Scaling Factor

IAN = Number of Manufacturing Firms

The number of manufacturing firms in the county is the product of the number of industrial firms and the normal percentage of industrial firms which are manufacturing firms. The normal percentage of industrial firms which are manufacturing firms is .06, which is one minus the normal percentage of industrial firms which are commercial firms. Equation 66 displays this relationship.

IAN.K = (I1.K)(1-IAFA) (66,18A)

IAN = Number of Manufacturing Firms

I1 = Number of Industrial Firms

IAFA = Normal Percentage--Commercial Firms

The labor situation's influence on the total labor situation is given by Equation 67. As the labor situation increases, its influence increases up to a point. At this point a further increase in the labor situation produces a decreasing influence. This reflects the negative aspects of an oversupply of labor due to high unemployment.

```
IAP.K = TABHL (IAPT, IAQ.K, -.075,                  (67,58A)
              .15, .025)

IAPT* = .0002/.0005/.0007/.002/.0017/.0016/         (67.1,C)
        .0015/.0013/.0011/.0009

  IAP = Labor Situation's Influence on the
        Total Labor Situation

 IAPT = Labor Situation's Influence--Table

  IAQ = Labor Situation as a Percentage of
        the Population
```

Equation 68 depicts the labor situation as a percentage of the population.

```
IAQ.K = IAR.K/P1.K                                  (68,20A)

  IAQ = Labor Situation as a Percentage
        of the Population

  IAR = Labor Situation

   P1 = Population
```

The labor situation of the county is defined as the difference between the county's available labor and its available jobs. Equation 69 describes this.

IAR.K = IAT.K − IAS.K (69,7A)

IAR = Labor Situation

IAT = Available Labor

IAS = Available Jobs

The available jobs in the county are the product of the number of industrial firms in the county and the normal number of jobs available per industrial firm which is a composite average based on national data. This product is shown in Equation 70.

IAS.K = (I1.K)(IASA) (70,12A)

IASA = 22 (70.1,C)

IAS = Available Jobs

IASA = Normal Jobs Available Per Industrial Firm

I1 = Industrial Firms

The county's available labor is the county's population multiplied by the normal fraction of the population which constitutes the labor force (a composite average) and the influence of the county's relative per capita income on this fraction. Equation 71 shows this representation.

IAT.K = (P1.K)(IATA)(IAU.K) (71,13A)

IATA = .382 (71.1,C)

IAT = Available Labor

IATA = Normal Fraction of the Population--Labor Force

IAU = Relative Per Capita Income's on the Normal Percentage--Labor Force

P1 = Population

Equation 72 displays the influence of the county's relative per capita income on the percentage of the population which constitutes the labor force. As the relative per capita income increases, its influence increases, until the effect of affluence causes its influence to decrease.

IAU.K = TABHL (IAUT, PAM.K, .85, 1.15, .05) (72,58A)

IAUT* = .98/1.02/1.06/1.04/1.03/1.01/1.00 (72.1,C)

IAU = Relative Per Capita Income's Influence on the Normal Percentage--Labor Force

IAUT = Relative Per Capita Income's Influence--Table

PAM = Relative Per Capita Income

Land Sector

Equation 73 represents the populated land in the county. It is an accumulation equation and consists of all residentially zoned and occupied land in the county. The initial value of populated land is 37,500 acres.

L1.K = L1.J + (DT)(LA.JK + 0) (73,1L)

L1 = 3.75E4 (73.1,6N)

L1 = Populated Land

LA = Net Yearly Change in Populated Land

Industrial land in the county consists of all industrially and commercially zoned land which is in use. It is depicted by Equation 74 which is an accumulation equation. The amount of industrial land in 1960 is 3,750 acres.

$$L2.K = L2.J + (DT)(LB.JK + 0) \qquad (74,1L)$$

$$L2 = 3.75E3 \qquad (74.1,6N)$$

L2 = Industrial Land

LB = Net Yearly Change in Industrial Land

Equation 75 is a technical necessity to insure that the land use in the county doesn't exceed the total amount of land in the county. When the value of vacant land is less than or equal to zero, the net yearly change in populated land must be zero. If the value of vacant land is greater than zero, the net yearly change in populated land assumes its calculated value. This equation insures the above conditions are met.

$$LA.KL = CLIP\ (LAA.K,\ 0,\ LAJ.K,\ 0) \qquad (75,51R)$$

LA = Net Yearly Change in Populated Land

LAA = Value of Net Yearly Change in Populated Land

LAJ = Value of Vacant Land

The value of the net yearly change in populated land is the product of three terms: the yearly population change, the per capita land use, and the influence of the per acre market value on land use. Equation 76 gives this expression.

LAA.K = (LAB.K)(LAC.K)(LAE.K) (76,13A)

LAA = Value of Net Yearly Change in Populated Land

LAB = Per Acre Market Value's Influence on the Net Change in Populated Land

LAC = Population Change

LAE = Per Capita Land Use

The influence of the per acre market value on the net yearly change in populated land is shown in Equation 77. As the per acre market value increases its influence increasingly depresses the net yearly change in populated land.

LAB.K = TABHL (LABT, GAH.K, 0, 50000, 10000) (77,58A)

LABT* = 1/.9/.8/.5/.2/.1 (77.1,C)

Equation 78 describes the net yearly change in population as the difference between the current population and last year's population.

LAC.K = P1.K - LAD.K (78,7A)

LAC = Net Yearly Change in Population

LAD = Last Year's Population

P1 = Population

Last year's population is specified by the "averaging" Equation 79 and is similar in form to the last year's relative per capita income of Equation 51. The averaging time is one year, and the initial value is 245,000 people.

LAD.K = LAD.J + (DT)(1/LADD)(P1.J-LAD.J) (79,3L)

LAD = 2.45E5 (79.1,6N)

LADD = 1 (79.2,C)

LAD = Last Year's Population

LADD = Averaging Time--Population

P1 = Population

Per capita land use in the county is the normal per capita land use modified by the influence of the percentage of vacant land left in the county. Equation 80 illustrates this. The normal per capita land use is based on DeKalb County data since national data was unavailable.

LAE.K = (LAEA)(LAF.K) (80,12A)

LAEA = .146 (80.1,C)

LAE = Per Capita Land Use

LAEA = Normal Per Capita Land Use

LAF = Percentage Vacant Land's Influence on Per Capita Land Use

The influence of the percentage of vacant land left in the county on per capita land use is shown in Equation 81. As the percentage of vacant land decreases, its influence on per capita increases. This reflects changing building patterns as land becomes scarce.

LAF.K = TABHL (LAFT, LAG.K, 0, 1, .2) (81,58A)

LAFT* = .7/.75/.8/.85/.9/1 (81.1,C)

LAF = Percentage Vacant Land's Influence on Per Capita Land Use

LAFT = Percentage Vacant Land's Influence--Table

LAG = Percentage of Vacant Land

Equation 82 gives the expression for the percentage of vacant land left in the county. It is the vacant land in the county divided by the total land area of the county.

LAG.K = LAH.K/LAGA (82,20A)

LAGA = 172E3 (82.1,C)

LAG = Percentage of Vacant Land

LAGA = Total Land Area--County

LAH = Vacant Land

Equation 83 is a technical necessity which prevents the vacant land in the county (as calculated by the program) from becoming negative.

LAH.K = MAX(LAJ.K,0) (83,56A)

LAH = Vacant Land

LAJ = Value of Vacant Land

The value of vacant land in the county is the county's total land area minus the populated and industrial land as defined previously. Equation 84 shows this.

LAJ.K = LAGA - L1.K - L2.K (84,8A)

LAJ = Value of Vacant Land

LAGA = Total Land Area--County

L1 = Populated Land

L2 = Industrial Land

The net change in industrial land per year is expressed in Equation 85, which is identical in form to Equation 75. This equation prevents the land use from exceeding the land area of the county.

$$LB.KL = CL1P\ (LBA.K,\ 0,\ LAJ.K,\ 0) \qquad (85{,}51R)$$

LB = Net Yearly Change in Industrial Land

LBA = Value of Net Yearly Change in Industrial Land

LAJ = Value of Vacant Land

The value of the net yearly change in industrial land is the product of the net yearly change in industrial firms, the normal land use per industrial firm, and the per acre market value's influence on industrial land use. Equation 86 gives this relationship. The normal land use per industrial firm is based on DeKalb County's data since national data was unavailable.

$$LBA.K = (LBB.K)(LBC.K)(LBAA) \qquad (86{,}13A)$$

$$LBAA = 1.3 \qquad (86.1{,}C)$$

LBA = Value of Net Yearly Change in Industrial Land

LBAA = Normal Land use per Industrial Firm

LBB = Per Acre Market Value's Influence on Industrial Land Use

LBC = Net Yearly Change in Industrial Firm

The influence of per acre market value on industrial land use is similar to its influence on the net yearly change in populated land, but less severe. As the per acre market value increases, industrial land use decreases. Equation 87 depicts this fact.

LBB.K = TABHL (LBBT, GAH.K, 0, 50000, 10000) (87,58A)

LBBT* = 1/1/.9/.8/.5/.2 (87.1,C)

LBB = Per Acre Market Value's Influence on Industrial Land Use

LBBT = Per Acre Market Value's Influence--Table

GAH = Per Acre Market Value

The net yearly change in industrial firms is described by Equation 88 as being the difference between the current number of industrial firms in the county and the number of industrial firms in the county last year.

LBC.K = I1.K - LBD.K (88,7A)

LBC = Net Yearly Change in Industrial Firms

LBD = Last Year's Number of Industrial Firms

L1 = Industrial Firms

The number of industrial firms in the county last year is given by the "averaging" Equation 89. It is similar to the "averaging" equations mentioned earlier. The averaging time is one year, and the initial value is 2,700 firms.

LBD.K = LBD.J + (DT)(1/LBDD)(I1.J-LBD.J) (89,3L)

LBD = 2.7E3 (89.1,6N)

LBDD = 1 (89.2,C)

LBD = Last Year's Number of Industrial Industrial Firms

LBDD = Averaging Time--Number of Industrial Firms

I1 = Industrial Firms

APPENDIX II

Program Listing

```
NOTE  GOVERNMENT SECTOR
NOTE
1L    G1.K=G1.J+(DT)(GA.JK-GB.JK)                      CASH BALANCE-GOVERNMENT
7R    GA.KL=GAA.K+GXB.K                                REVENUE RATE
13A   GAA.K=(GADA)(GAB.K)(GAF.K)                       TAXES COLLECTED
58A   GAB.K=TABHL(GABT,GAC.K,.5,5,.5)                  TAX RATIO
3L    GAC.K=GAC.J+(DT)(1/GACD)(GAD.J-GAC.J)            TAX RATIO NEEDED-PERCEIVED
20A   GAD.K=GAE.K/GADA                                 TAX RATIO NEEDED
20A   GAE.K=GAK.K/GAF.K                                MILLAGE NEEDED
12A   GAF.K=(.4)(GAG.K)                                ASSESSED VALUE-PROPERTY
12A   GAG.K=(LAGA)(GAH.K)                              MARKET VALUE-PROPERTY
13A   GAH.K=(GAJ.K)(PAJ.K)(GAHA)                       MARKET VALUE/ACRE
58A   GAJ.K=TABHL(GAJT,PAJ.K,.25,3,.25)                INFL H/L ON MARKET VALUE/A
7A    GAK.K=GAV.K-GAL.K                                TAXES NEEDED
13A   GAL.K=(GAM.K)(GAN.K)(GAR.K)                      PROJECTED OTHER FUNDS
58A   GAM.K=TABHL(GAMT,TIME.K,0,100,10)                EXT. OTHER FUNDS/PERSON
14A   GAN.K=P1.K+(GAND)(GAP.K)                         PROJECTED POPULATION
21A   GAP.K=(1/GAQD)(P1.K-GAQ.K)                       POPULATION GROWTH
3L    GAQ.K=GAQ.J+(DT)(1/GAQD)(P1.J-GAQ.J)             PERCEIVED POPULATION
58A   GAR.K=TABHL(GART,GAS.K,-.1,.1,.02)               INFL LIMIT COMP ON REVENUE
7A    GAS.K=.14-GAT.K                                  DEBT LIMIT COMPARISON
20A   GAT.K=GAU.K/GAF.K                                DEBT AS A % OF ASSESSED VA
12A   GAU.K=(-1)(G1.K)                                 DEBT-GOVERNMENT
12A   GAV.K=(GAN.K)(GAW.K)                             PROJECTED EXPENSES
14A   GAW.K=GXA.K+(GAWD)(GAY.K)                        PROJECTED EXPENSES/PERSON
21A   GAY.K=(1/GAZD)(GXA.K-GAZ.K)                      EXPENSES/PERSON GROWTH
3L    GAZ.K=GAZ.J+(DT)(1/GAZD)(GXA.J-GAZ.J)            PERCEIVED EXPENSES/PERSON
20A   GXA.K=GB.JK/LAD.K                                EXPENSES/PERSON
13A   GXB.K=(GAM.K)(P1.K)(GAR.K)                       OTHER FUNDS
13R   GB.KL=(GBA.K)(GBB.K)(P1.K)                       EXPENSE RATE
58A   GBA.K=TABHL(GBAT,TIME.K,0,100,10)                EXT. EXPENSE/PERSON
58A   GBB.K=TABHL(GBBT,GAS.K,-.1,.1,.02)               DEBT LIMIT COMPARISON INFL
NOTE
NOTE  POPULATION SECTOR
NOTE
1L    P1.K=P1.J+(DT)(PA.JK+0)                          POPULATION
13R   PA.KL=(P1.K)(PAA.K)(PAD.K)                       YEARLY CHANGE IN POPULATIO
3L    PAA.K=PAA.J+(DT)(1/PAAD)(PAB.J-PAA.J)            PERC.D REL ATTRAC
12A   PAB.K=(PAC.K)(PAE.K)                             SCALE MODIFIER REL ATTRAC
58A   PAC.K=TABHL(PACT,PAD.K,.005,.03,.005)            REL ATTRAC SCALE MULT
58A   PAD.K=TABHL(PADT,TIME.K,0,100,10)                % CHANGE IN POPULATION SMS
58A   PAE.K=TABHL(PAET,PAF.K,.91,1.09,.02)             REL. ATTRAC. CONVERSION TA
17A   PAF.K=(PAH.K)(PAL.K)(.5)+(PAP.K)(1)(.5)+(PAG.K)(1)(1) REL ATTRAC
58A   PAG.K=TABHL(PAGT,PAD.K,.005,.03,.005)            R.A.(X/Y) MODIFIER
58A   PAH.K=TABHL(PAHT,PAJ.K,.2,2,.2)                  H/A (ABSOLUTE) INFL ON REL
46A   PAJ.K=(P1.K)(PAK.K)(PAJA)/((LAGA)(1)(1))         HOUSING DENSITY
58A   PAK.K=TABHL(PAKT,LAG.K,0,1,.2)                   INFL % V.L. ON HOUSE/PERSO
58A   PAL.K=TABHL(PALT,PAM.K,.2,2,.2)                  H/A (REL.) INFL ON REL ATT
20A   PAM.K=PAJ.K/PAN.K                                RELATIVE HOUSING DENSITY
58A   PAN.K=TABHL(PANT,TIME.K,0,100,10)                EXT. HOUSING DENSITY
58A   PAP.K=TABHL(PAPT,PAQ.K,.8,1.15,.05)              INFL REL PER CAP INC ON R.
12A   PAQ.K=(PAR.K)(PAU.K)                             RELATIVE PER CAPITA INCOME
12A   PAR.K=(PAS.K)(PAT.K)                             INFL OF R.A.,SIZE ON CHANG
58A   PAS.K=TABHL(PAST,PAA.K,-4,6,1.67)                INFL OF R.A. ON CHANGE R.P
58A   PAT.K=TABHL(PATT,PAU.K,.85,1.25,.05)             INFL PREVIOUS RPCI ON CHAN
3L    PAU.K=PAU.J+(DT)(1/PAUD)(PAQ.J-PAU.J)            PREVIOUS REL PER CAPITA IN
NOTE
```

```
NOTE   INDUSTRY SECTOR                                      
NOTE
1L     I1.K=I1.J+(DT)(IA.JK+0)                              INDUSTRIAL FIRMS
12R    IA.KL=(I1.K)(IAA.K)                                  RATE OF CHANGE INDUSTRIAL I
3L     IAA.K=IAA.J+(DT)(1/IAAD)(IAB.J-IAA.J)                DELAYED RATE OF CHANGE IND
7A     IAB.K=IAC.K+IAK.K                                    % RATE OF CHANGE IND FIRMS
12A    IAC.K=(IAD.K)(IAG.K)                                 TOTAL NEED FOR IND INFL
58A    IAD.K=TABHL(IADT,IAE.K,2,16,2)                       INFL # COMM FIRMS ON % CHAI
12A    IAE.K=(IAF.K)(IAEA)                                  SCALED # OF COMMERCIAL FIR
12A    IAF.K=(I1.K)(IAFA)                                   # COMMERCIAL FIRMS
58A    IAG.K=TABHL(IAGT,IAH.K,-.006,.008,.002)              NEED FOR IND INFL ON % CHAI
7A     IAH.K=IAHA-IAJ.K                                     NEED FOR INDUSTRY
20A    IAJ.K=IAF.K/P1.K                                     # COMMERCIAL FIRMS/PERSON
12A    IAK.K=(IAL.K)(IAP.K)                                 TOTAL LABOR SITUATION INFL
58A    IAL.K=TABHL(IALT,IAM.K,0,1.5,.5)                     INFL # MANF FIRMS ON % CHAI
12A    IAM.K=(IAN.K)(IAEA)                                  SCALED # MANF FIRMS
18A    IAN.K=(I1.K)(1-IAFA)                                 # MANUFACTURING FIRMS
58A    IAP.K=TABHL(IAPT,IAQ.K,-.075,.15,.025)               LABOR SIT INFL ON % IND CH.
20A    IAQ.K=IAR.K/P1.K                                     LABOR SITUATION AS % POP
7A     IAR.K=IAT.K-IAS.K                                    LABOR SITUATION
12A    IAS.K=(I1.K)(IASA)                                   AVAILABLE JOBS
13A    IAT.K=(P1.K)(IATA)(IAU.K)                            AVAILABLE LABOR
58A    IAU.K=TABHL(IAUT,PAQ.K,.85,1.15,.05)                 INFL REL PER CAP INC ON %
NOTE
NOTE   LAND SECTOR
NOTE
1L     L1.K=L1.J+(DT)(LA.JK+0)                              POPULATED LAND
1L     L2.K=L2.J+(DT)(LB.JK+0)                              INDUSTRIAL LAND
51R    LA.KL=CLIP(LAA.K,0,LAJ.K,0)                          NET CHANGE POP. LAND
13A    LAA.K=(LAB.K)(LAC.K)(LAE.K)                          VALUE NET CHANGE POP. LAND
58A    LAB.K=TABHL(LABT,GAH.K,0,50000,10000)                INFL MV/ACRE ON POP LAND U
7A     LAC.K=P1.K-LAD.K                                     POPULATION CHANGE
3L     LAD.K=LAD.J+(DT)(1/LADD)(P1.J-LAD.J)                 LAST YEAR'S POPULATION
12A    LAE.K=(LAEA)(LAF.K)                                  LAND/PERSON
58A    LAF.K=TABHL(LAFT,LAG.K,0,1,.2)                       INFL % V.L. ON LAND/PERSON
20A    LAG.K=LAH.K/LAGA                                     % VACANT LAND
56A    LAH.K=MAX(LAJ.K,0)                                   VACANT LAND
8A     LAJ.K=LAGA-L1.K-L2.K                                 VALUE VACANT LAND
51R    LB.KL=CLIP(LBA.K,0,LAJ.K,0)                          NET CHANGE INDUSTRIAL LAND
13A    LBA.K=(LBB.K)(LBC.K)(LBAA)                           VALUE NET CHANGE IND. LAND
58A    LBB.K=TABHL(LBBT,GAH.K,0,50000,10000)                INFL MV/ACRE ON IND LAND U
7A     LBC.K=I1.K-LBD.K                                     INDUSTRY CHANGE
3L     LBD.K=LBD.J+(DT)(1/LBDD)(I1.J-LBD.J)                 LAST YEAR'S INDUSTRY
NOTE
NOTE   PLOT VARIABLES
NOTE
7A     GXX.K=GBA.K-GAM.K                                    'NET' PER CAP EXPS &OTHER
12A    PXA.K=(PAH.K)(PAL.K)                                 HOUSING DENSITY (REL,ABS)
NOTE
NOTE   INITIAL CONDITIONS
NOTE
6N     G1=-42.4E6                                           CASH BALANCE-GOVERNMENT
6N     GAC=.61                                              TAX RATIO NEEDED-PERCEIVED
6N     GAQ=1.97E5                                           PERCEIVED POPULATION
6N     GAZ=132                                              PERCEIVED EXPENSES/PERSON
6N     P1=2.57E5                                            POPULATION
6N     PAA=2.5                                              PERCEIVED RELATIVE ATTRACT
```

```
6N    PAU=1.096                                          LAST YEAR,S INCOME RATIO
6N    I1=2.92E3                                          INDUSTRIAL FIRMS
6N    IAA=.08                                            DELAYED RATE OF CHANGE IND
6N    L1=3.75E4                                          POPULATED LAND
6N    L2=3.75E3                                          INDUSTRIAL LAND
6N    LAD=2.45E5                                         LAST YEAR,S POPULATION
6N    LBD=2.7E3                                          LAST YEAR,S INDUSTRY
NOTE
NOTE  CONSTANTS
NOTE
C     GACD=5        YEARS                                PERC TIME TAX RATIO NEEDED
C     GADA=.042     DIMENSIONLESS                        NORMAL MILLAGE
C     GAHA=1E4      $/ACRE                               SCALE FACTOR MARKET VALUE/
C     GAND=1        YEARS                                PROJ TIME-POPULATION
C     GAQD=5        YEARS                                PERC TIME-POPULATION
C     GAWD=1        YEARS                                PROJ TIME-EXPS/PERSON
C     GAZD=2        YEARS                                PERC TIME-EXPENSES/PERSON
C     PAAD=10       YEARS                                PERC TIME-REL ATTRAC BY PO
C     PAJA=.32      HOUSE/PERSON                         NORMAL PER CAPITA HOUSING
C     PAUD=1        YEARS                                LAST YEAR
C     IAAD=5        YEARS                                DELAY TIME RATE OF CHANGE
C     IAEA=1E-3     DIMENSIONLESS                        SCALING FACTOR
C     IAFA=.94      COMM FIRMS/TOTAL FIRMS               NORMAL % COMMERCIAL FIRMS
C     IAHA=.018     COMM FIRMS/PERSON                    NORMAL # COMMERCIAL FIRMS/
C     IASA=22       JOBS/INDFIRM                         NORMAL JOBS/INDUSTRIAL FIR
C     IATA=.382     DIMENSIONLESS                        NORMAL % POP=LABOR FORCE
C     LADD=1        YEARS                                PREVIOUS YEAR
C     LAEA=.146     ACRES/PERSON                         LAND USE/PERSON
C     LAGA=172E3    ACRES                                TOTAL LAND AREA-COUNTY
C     LBAA=1.3      ACRES/FIRM                           LAND USE/INDUSTRIAL FIRM
C     LBDD=1        YEAR                                 PREVIOUS YEAR
NOTE
NOTE  TABHL CONSTANTS
NOTE
C     GABT*=.600/1/1.4/1.8/2.2/2.5/2.8/3/3.2/3.4 DIMENSIONLESS
C     GAJT*=1.25/1.8/1.85/1.9/1.95/2/2.05/2.1/2.15/2.2/2.25/2.3 $/ACRE
C     GAMT*=70/140/252/373/445/464/482/500/520/540/560 $/PERSON/YR
C     GART*=1.2/1.2/1.2/1.2/1.2/1.2/1.15/1.1/1.05/1/1 DIMENSIONLESS
C     GBAT*=169/270/400/516/578/636/700/770/847/932/1025 $/PERSON/YR
C     GBBT*=.65/.65/.65/.65/.65/.75/.8/.85/.9/.95/1 DIMENSIONLESS
C     PACT*=5.85/2.94/1.97/1.48/1.23/1 DIMENSIONLESS
C     PADT*=.03/.0275/.025/.0225/.02/.0175/.015/.0125/.01/.0075/.005 %/YEAR
C     PAET*=-2/-1.33/-.67/0/.67/1.33/2/2.67/3.33/4
C     PAGT*=.025/.02/.015/.01/.005/0 %/YEAR
C     PAHT*=.96/.89/.85/.84/.837/.833/.83/.827/.823/.82 DIMENSIONLESS
C     PAKT*=1/.97/.95/.93/.91/.9 DIMENSIONLESS
C     PALT*=1.2/1.175/1.14/1.11/1.07/1.03/1.02/1.01/1/.99 DIMENSIONLESS
C     PANT*=.28/.41/.6/.75/.92/1.1/1.3/1.47/1.61/1.73/1.82 HOUSE/ACRE
C     PAPT*=.93/.93/.98/1/1.1/1.105/1.11 DIMENSIONLESS
C     PAST*=.999/.9995/1/1/1/1.0034/1.0068 DIMENSIONLESS
C     PATT*=1/1/1/1/.998/.996/.994/.992/.990 DIMENSIONLESS
C     IADT*=3.5/1.8/1.3/1.2/1.1/1/1.7/2.5 DIMENSIONLESS
C     IAGT*=-.013/-.007/-.003/.002/.011/.016/.018/.019 %/YEAR
C     IALT*=7.8/5.5/1/3.9 DIMENSIONLESS
C     IAPT*=.0002/.0005/.0007/.002/.0017/.0016/.0015/.0013/.0011/.0009 %/YE
C     LABT*=1/.9/.8/.5/.2/.1 DIMENSIONLESS
C     LAFT*=.7/.75/.8/.85/.9/1 DIMENSIONLESS
```

```
C      LBBT*=1/1/.9/.8/.5/.2 DIMENSIONLESS
PRINT  1)GAU,GAT,GAB/2)GB,GA,GAA/3)GXB/4)P1,PAJ,PAM/5)PAQ/6)I1,IAF,IAN/7)
X      IAS,IAT/8)L1,L2,LAG/9)LAE
C      IAUT*=.98/1.02/1.06/1.04/1.03/1.01/1 DIMENSIONLESS
PLOT   GAU=G(0,.5E9)/P1=P(0,1.5E6)/I1=I(0,25E3)/LAG=V(0,1)
SPEC   DT=1/LENGTH=100/PRTPER=0/PLTPER=0
END
```

APPENDIX III

Parameter Values

As stated in Chapter V, the model presented in this thesis is a modification of an earlier formulation as the result of a sensitivity analysis. One of the objectives of the modification was to quantify as many parameter values as accurately as possible within the limitations of the thesis requirements. Data were collected from the 1956, 1962, 1966, and 1972 County and City Data Books[21] from the 90 counties of the Standard Metropolitan Statistical Areas shown in Table 18. The parameter values to be specified fell into three categories: constants, initial conditions, and "TABHL" functions. The constants were derived from the data base mentioned above and represent either projection and perception times determined by interviews, scaling factors, or composite averages of the 90-county population. The initial conditions characterize DeKalb County in 1960 and were compiled from "Atlanta Silhouettes-People, Jobs, and Land: Population and Economy-Report Number One," Systems Report-A.R.C. 1970-1971 Inventories," and the records of the Georgia State Department of Revenue-Property Tax Unit in addition to those sources mentioned previously. The "TABHL" functions were determined either by interviews with knowledgeable officials of the DeKalb County Government or by a modified interval averaging technique using the data base of the 90-county population. The following DeKalb County Government departments were involved in the interviewing process: Financial Services, Comprehensive Planning, Budget, and Tax. In addition, the Atlanta Regional Commission was contacted.

Table 18. Data Base--Standard Metropolitan Statistical Areas Sampled and Selected Characteristics

S.M.S.A.	Number of Counties	Listing of Selected Base Characteristics
Albany, New York	4	Population
Cincinnati, Ohio	7	Labor Force
Cleveland, Ohio	4	Employment
Dallas, Texas	6	Per Capita Income
Dayton, Ohio	4	Industrial Firms
Greensboro, North Carolina	4	Commercial Firms
Houston, Texas	5	Manufacturing Firms
Indianapolis, Indiana	8	Houses
Kansas City, Missouri	6	Land Area
Milwaukee, Wisconsin	4	*Debt
Newark, New Jersey	3	*Revenues
New Orleans, Louisiana	4	*Property Taxes
Pittsburgh, Pennsylvania	4	*Assessed Value
Rochester, New York	4	*Expenses
St. Louis, Missouri	7	*Populated Land
Syracuse, New York	3	*Industrial Land
Toledo, Ohio	3	*Vacant Land
Washington, D. C.	10	
	90	*Atlanta S.M.S.A. only

This chapter will discuss the parameter values under the sections: initial conditions, constants, and "TABHL" functions. In each section the general rationale and methodological techniques employed in the determination of the parameter values will be discussed first, followed by the listing of the parameter values, their data sources, and any crucial assumptions involved. The data sources will be referred to by their respective bibliography listings.

Initial Conditions

The initial conditions characterize DeKalb County in 1960. They are associated with two types of accumulations: the "physical" type of accumulation (1L Equation form) and the "averaging" or "perception" type of accumulation (3L equation form). The determination of the initial conditions of the "physical" accumulations is straightforward. They are merely the values of the respective accumulations in 1960 and are obtained directly from the data sources stated on the preceding page. The determination of the initial conditions of the "averaging" or "perception" accumulations is somewhat more complex. It is assumed that the initial condition of the "averaging" or "perception" accumulation is the value of the actual physical accumulation at a point in time in the past equal to the present minus the "averaging" (or "perception") time. For example, if the "averaging" time is five years, the initial value (1960) of the "averaging" accumulation equals the value of the actual physical accumulation in 1955. The "averaging" or "perception" times of these accumulations will be stated with their respective initial conditions. It is noted that data is not available for every year from 1950 to 1960, so linear interpolation was used to determine initial conditions which fell between data points. This is denoted by ( ) where employed.

Initial Conditions

1) Government Cash Balance

Source: 21,22

	1957	1960	1962
DeKalb County Government Indebtedness	49E6	(75.4E6)	93E6
-Cash, Security on Hand for Debt Retirement	29E6	(33.0E6)	37E6
Net Debt		42.4E6	

Initial Condition--Government Cash Balance = $42,400,000

2) Tax Ratio Needed--Perceived

Source: 31

	1955	1960	1965
Millage Rate--DeKalb County	--	28.70	32.20
Average Millage Rate--S.M.S.A.	--	41.80	41.80
Actual Tax Ratio	(.61)	.69	.77

The tax ratio is the ratio of the county's millage rate to the average millage rate of the governmental units in Atlanta. It is assumed that the change in the tax ratio from 1955 to 1960 is the same as that from 1960 to 1965 since data in 1950 was unavailable. It is noted that the perception time is five years.

Initial Condition--Tax Ratio Needed, Perceived = .61

3) Perceived Population

Source: 21,22

	1950	1955	1960
DeKalb County Population	136,000	197,000	257,000

The perception time is five years.

Initial Condition--Perceived Population = 197,000 people.

4) Perceived Per Capita Expenses

Source: 22,23

	1957	1958	1962
DeKalb County Government--Total Expenses	27E6	(31E6)	46E6
DeKalb County Population		(233E3)	
Per Capita Expenses		132	

The perception time is two years in this case. The population in 1958 is an interpolation between the values of the population in 1950 and 1960.

Initial Condition--Perceived Per Capita Expenses = \$132/person/year

5) Population

Source: 22

	1960
DeKalb County Population	257,000 people

6) Perceived Relative Attractiveness

Source: 21

The perception time in this instance is ten years, so the initial condition of the perceived relative attractiveness is equal to the value of the actual relative attractiveness in 1950. Since this is a derived measure, the model formulas are employed by using 1950 data and the appropriate "TABHL" functions to determine the 1950 value of actual relative attractiveness. The formulas are:

$$\text{Relative Attractiveness} = .5\left[\begin{pmatrix}\text{influence of}\\ \text{absolute}\\ \text{housing density}\end{pmatrix}\begin{pmatrix}\text{influence of}\\ \text{relative}\\ \text{housing density}\end{pmatrix} + \begin{matrix}\text{influence of}\\ \text{relative per}\\ \text{capita income}\end{matrix}\right] + \begin{matrix}\text{influence of yearly}\\ \text{\% change in population}\\ \text{SMSA}\end{matrix}$$

$$\text{Actual Relative Attractiveness} = \begin{pmatrix}\text{relative}\\ \text{attractiveness}\\ \text{influence}\end{pmatrix}\begin{pmatrix}\text{influence of yearly \%}\\ \text{change in population--}\\ \text{SMSA}\end{pmatrix}$$

	Absolute Housing Density	Relative Housing Density	Relative Per Capita Income	% Change population SMSA
1950 DeKalb Value	.21	1.35	1.25	.03
Corresponding Influence	.96	1.0225	1.11	0
Relative Attractiveness	.5[(.96)(1.0225) + 1.11] + 0 = 1.045			
Actual Relative Attractiveness	(2.50)(1) = 2.50			

Initial Condition--Perceived Relative Attractiveness = 2.50

7) Last Year's Relative Per Capita Income

Source: 21,22,24

	1959	1960	1970
DeKalb County Per Capita Income		2.10	3.74
Atlanta S.M.S.A. Per Capita Income		1.90	3.50
Relative Per Capita Income	(1.096)	1.094	1.071

The "averaging" time is one year.

Initial Condition--Last Year's Relative Per Capita Income = 1.096

8) Industrial Firms

Source: 22

	1960
Number of Industrial Firms in DeKalb County	2,920 firms

9) Delayed Yearly Percentage Rate of Change of Industrial Firms

Source: 21

It is assumed that the yearly percentage rate of change in 1955 is the average yearly percentage rate of change for the five years prior to 1955 (1949-1954). The delay time is five year.

	1949	1954
Number of Industrial Firms in DeKalb County	1,074	1,560
Average Yearly Percentage Change	.08/year	

Initial Condition--Delayed Yearly Percentage Rate of Change of Industrial Firms = .08/year

10) Populated Land

Source: 50,51

	DeKalb			S.M.S.A.		
	Populated	Industrial	Vacant	Populated	Industrial	Vacant
1960	(37,500)	(3,750)	(130,750)	126,357	14,718	958,975
1970	50,930	7,481	113,589	212,275	39,258	848,467

It is assumed that the proportion of vacant land to total land and the proportion of industrial land to populated land varied in DeKalb as it did in the Atlanta metropolitan area from 1960 to 1970, since data for DeKalb was unavailable for 1960.

Initial Condition--Populated Land = 37,500 acres

11) Industrial Land

Source: 50,51

Initial Condition--Industrial Land = 3,750 acres (see 10 above)

12) Last Year's Population

Source: 21,22

	1950	1959	1960
DeKalb County Population	136,000	(245,000)	257,000

The "averaging" time is one year.

Initial Condition--Last Year's Population = 246,000 people

13) Last Year's Industrial Firms

Source: 21,23

	1954	1959	1963
Number of Industrial Firms in DeKalb County	1,560	(2,700)	3,595

The "averaging" time is one year.

Initial Condition--Last Year's Industrial Firms = 2,700 firms

Constants

The constants are composed of perception and projection times, scaling factors, and "normal" constants. The perception and projection times were determined by interviews and represent "best guesses." They are shown in Table 19 accompanied by the DeKalb County Government department(s) interviewed. The scaling factors are merely technical adjustments intended to facilitate the use of "TABHL" functions. The "normal" constants are derived from national data (the 90 counties mentioned in Table 18) where possible and from DeKalb County data where national data is unavailable. The "normal" constants based on national data are composite averages of the 90-county data. In the model formulation the "normal" constants are modified by influences of county characteristics to produce their county analogs. This formulation is preferred since it more clearly identifies the interrelationships between county characteristics. It is felt that this is legitimate since the characteristics which are averaged are closely grouped in magnitude over the 90-county population, and thus the "normal" constants are representative. The constants, their data sources, and the relevant data are presented below.

1) Normal Millage Rate (S.M.S.A.)

Source: 31

County	1960	1963	1964	1965	1966	1970
Clayton	.051	.052	.030	.030	.032	.041
Cobb	.051	.036	.040	.044	.044	.039
DeKalb	.029	.032	.032	.032	.032	.039
Gwinnett	.036	.043	.045	.047	.039	.034
Fulton	.051	.052	.052	.053	.053	.049

Average Millage Rate = .042

Table 19. Perception, Projection Times

Time	Value	Department(s) Interviewed
Perception--Tax Ratio Needed	5	Financial Services
Projection--Population	1	Budget, Financial Services
Perception--Population	5	Budget
Projection--Per Capita Expenses	1	Budget, Financial Services
Perception--Per Capita Expenses	2	Budget
Perception--Relative Attractiveness	10	Comprehensive Planning
Average--Relative Per Capita Income	1	--
Delay--Industrial Yearly Rate of Change	5	Comprehensive Planning
Average--Population	1	--
Average--Industrial Firms	1	--

2) Scale Factor--Market Value/Acre

This factor is 10,000 and is used merely to facilitate the use of its respective "TABHL" function.

3) Normal Per Capita Housing

Source: 22

	1960
Total Number Houses (90 counties)	9,300,000
Total Population (90 counties)	28,700,000
Normal Per Capita Housing	.32

Normal Per Capita Housing = .32 houses/person

4) Scale Factor--Number of Commercial Firms

This factor is .001 and is similar to the one mentioned above.

4) Normal Fraction--Commercial Firms

Source: 22

This constant represents the normal fraction of industrial firms which are commercial firms. It is a composite average of the 90-county population.

	1958
Total Number of Industrial Firms (90 counties)	427,000
Total Number of Commercial Firms (90 counties)	400,000
Normal Fraction--Commercial Firms	.94

Normal Fraction--Commercial Firms = .94

6) Normal Per Capita Commercial Firms

Source: 22

This also is a composite average of the 90-county population. The population is an interpolation between 1950 and 1960.

	1958
Total Number of Commercial Firms (90 counties)	400,000
Total Population (90 counties)	(22,000,000)
Normal Per Capita Commercial Firms	.018

Normal Per Capita Commercial Firms = .018 firms/person

7) Normal Jobs Available Per Industrial Firm

Source: 22

In the determination of this constant (a composite average) it is assumed that the total number of jobs available equals the total number of persons employed (over the 90 counties) increased by ten percent (to account for jobs available in industry which are not filled).

	1958
Total Employment (90 counties)	8,600,000
Total Industrial Firms (90 counties)	427,000
Employment/Industrial Firm	20
Jobs Available/Industrial Firm	22

Normal Jobs Available Per Industrial Firm = 22 jobs/industrial firm

8) Normal Fraction--Labor Force

Source: 22

	1960
Total Labor Force (90 counties)	8,740,000
Total Population (90 counties)	22,850,000
Normal Fraction--Labor Force	.382

Normal Fraction--Labor Force = .382

9) Per Capita Land Use (DeKalb)

Source: 22,50,51

This constant uses DeKalb County data, since national data is unavailable.

	1960	
DeKalb Populated Land	37,500	(see initial conditions-number 10)
DeKalb Population	257,000	
Per Capita Land Use	.146	

Per Capita Land Use = .146 acres/person

10) Total Land Area--DeKalb County

Source: 22

This constant is directly obtained from the source listed above.

Total Land Area--DeKalb County = 172,000 acres

11) Land Use Per Industrial Firm

Source: 22,50,51

The data pertaining to this constant is unavailable nationally, so DeKalb County data was employed.

DeKalb Industrial Land	3,750	(see initial conditions-number 11)
Number of Industrial Firms in DeKalb	2,920	
Land Use/Industrial Firm	1.31	

Land Use Per Industrial Firm = 1.3

TABHL Constants

The "TABHL" function constants to be presented in this section were determined either by interviews with knowledgeable persons (government and land sectors) or by an interval averaging technique (population and industrial sectors). The data base from which these constants are derived is the 90-county base shown in Table 18.

The technique used to generate "TABHL" function constants involves 1) selecting a population of representative counties (between 600,000 and 2,500,000 in population in 1960) from which to sample, 2) ascertaining the dependent and independent variables of the respective "TABHL" functions, 3) constructing tables in which the values of the independent variable(s) is (are) divided into intervals of ascending magnitude, 4) assigning occurrences of the variables from the population of the counties (the 90 counties in Table 18) within each interval, 5) determining the average value of the variables (both dependent and independent) interval within each interval, and 6) formulating the appropriate "TABHL" function from these interval averages.

In the two dimensional case (one dependent and one independent variable) a direct relationship is assumed. The independent variable is divided into intervals and occurrences are assigned to their respective intervals. For each county (data point) there is a value of the dependent variable which is assigned to the interval of the corresponding value of the independent variable. This is done for the 90 counties, and the interval averages of the independent variable are determined. Then the average values of the dependent variable, occurring within the intervals are found. The "TABHL" function is thus determined by assuming that the interval average value of the independent variable produces the average occurrence value of the dependent variable for that particular interval. In the three-dimensional case (two independent variables) the same procedure is followed except that the interval averages of one of the independent variables must be scaled to insure the proper magnitude and sign of the resultant dependent variable. An example of the interval averages of the independent variable(s) and the average occurrence values of the dependent variable are presented with their respective derived "TABHL" functions. The dependent variable is shown directly above the independent variable in the format of this presentation.

Two Dimensional Case

This example will illustrate the generation of the "TABHL" function which represents the influence of the county's relative per capita income (the independent variable) on the fraction of the county's population which constitutes the labor force (the dependent variable). These variables are defined below.

$$\text{Relative Per Capita Income} = \frac{(\text{Per Capita Income})\ \text{county}}{(\text{Per Capita Income})\ \text{SMSA}}$$

$$\text{Fraction of Population Which Composes the Labor Force} = \frac{\text{Labor Force}}{\text{Population}}\quad \text{county}$$

The table on page 127 shows the intervals into which the independent variable has been divided and the occurrences (from the 90-county population) within each interval. The interval averages are also given.

The table below shows the derived "TABHL" function. It is noted that the range of the independent variable (the relative per capita income) has been reduced from .50 to 1.26 to .85 to 1.15 for use in the model. Also, the fraction of the population which composes the labor force has been modified to reflect the influence of the relative per capita income on the "normal" fraction of the population which composes the labor force. This is consistent with the model formulation and is accomplished by dividing the various fractions (associated with the respective interval averages [illegible] the relat[illegible] income) by

Interval	≤ .60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30
Relative Per Capita Income	.49 .51 .49	.67 .60 .60 .62 .68 .62 .64	.80 .76 .77 .80 .74 .79 .78 .76 .79 .77 .79 .79 .80 .80	.85 .88 .89 .89 .81 .81 .89 .88 .85 .86 .85 .82 .87 .86 .85 .87 .87 .82 .88	1.00 .98 .97 .95 .92 .95 .91 .94 .92 .94 .97 .94 .94 .94 .99 .94 .97 1.00 .97 .93	1.06 1.06 1.06 1.03 1.09 1.06 1.01 1.01 1.04 1.06 1.07 1.06 1.04 1.05 1.05 1.04 1.03	1.15 1.12 1.20 1.20	1.25 1.24 1.30 1.25
Interval Average	.50	.63	.78	.86	.95	1.04	1.16	1.26
Occurrence Average	.442	.338	.374	.374	.403	.092	.382	.364
Fraction Which is Labor Force	.593 .294 .440	.412 .346 .374 .326 .347 .310 .248	.350 .333 .323 .410 .410 .376 .343 .322 .432 .348 .350 .347 .350 .348	.465 .354 .343 .388 .416 .324 .350 .352 .360 .355 .378 .349 .347 .356 .425 .415 .384 .443 .393 .382	.399 .389 .386 .380 .428 .385 .364 .435 .468 .409 .363 .465 .393 .402 .388 .368 .415 .434 .407 .363 .453 .460	.418 .420 .396 .392 .410 .423 .220 .378 .394 .413 .412 .404 .428 .390 .415 .420 .415	.395 .368 .380 .382	.396 .386 .312 .363

the respective interval averages of the relative per capita income) by the "normal" fraction of the population which composes the labor force (.382).

Interval Averages

Fraction of Population	.374	.403	.392	.382	.364
Relative Per Capita Income	.86	.95	1.04	1.16	1.26

Derived "TABHL" Function

Influence of Relative Per Capita Income	.98	1.02	1.06	1.04	1.03	1.01	1.00
Relative Per Capita Income	.85	.90	.95	1.00	1.05	1.10	1.15

Three Dimensional Case

This example will show the generation of two related "TABHL" functions. One represents the influence of the county's absolute housing density on the county's relative attractiveness, the other depicts the influence of the county's relative densing density on its relative attractiveness. These variables are defined below.

$$\text{Absolute Housing Density} = \frac{\text{Total Number Dwelling Units}}{\text{Total Land Area}}$$

$$\text{Relative Housing Density} = \frac{\text{Housing Density--County}}{\text{Housing Density--SMSA}}$$

$$\text{Relative Attractiveness} = \frac{\left(\dfrac{\text{Population 1970}}{\text{Population 1960}}\right)\ \text{county}}{\left(\dfrac{\text{Population 1970}}{\text{Population 1960}}\right)\ \text{SMSA}}$$

The following table shows the intervals into which the independent variables have been divided and the occurrences of the dependent variable (the county's relative attractiveness) within these intervals.

Absolute Housing Density: Interval	Interval Average		Relative Housing Density: .00-.20	.21-.40	.41-.60	.61-2.00	2.01-5.00	>5.00	
		Interval Average	.13	.30	.50	1.22	2.91	14.60	
			.18 .04 .10 .09 .11. .12 .13 .12 .18 .20 .17 .09 .13 .14 .12 .01 .13 .18 .17 .02 .09 .18 .19 .15 .18 .10 .14 .12 .20 .15 .12 .18	.31 .29 .23 .38 .23 .32 .25 .22 .21 .34 .32 .30 .25 .29 .38 .27 .31 .38 .27 .27 .40 .22 .28 .27 .22 .31 .35 .34 .25	.46 .43 .54 .50 .51 .58 .46 .44 .54 .59 .58 .43 .48 .49 .45	1.61 1.94 1.82 1.58 .82 .69 1.26 1.96 .67 .74 1.56 1.14 .65 .83 .96 1.25 1.23	2.3 2.9 2.2 2.2 5.0 3.3 3.6 2.2 2.5 2.9 3.8 4.5 2.8 2.7 2.7 3.2 2.5 2.8 2.2	13.6 29.2 6.7 5.8 5.8 26.3	Occurrences Averages Relative Attractiveness
.00-.10	.05	.05 .07 .03 .01 .03 .05 .04 .08 .03 .01 .07 .05 .07 .06 .03 .03 .05 .04 .05 .02 .02 .05 .09 .05 .04 .03 .02 .04 .06 .06 .06 .08 .10 .05 .07 .09 .05 .08 .09 .07 .03 .02 .07 .04 .04 .04 .05 .06 .03 .05 .03 .04 .06 .02 .05 .03 .02 .03 .03 .07 .03 .10	1.21 .93 1.11 1.17 .90 1.43 1.25 .72 1.33 1.39 .72 1.40 1.37 1.15 1.60 1.42 .72 1.44 1.28 1.20 1.58 1.38 1.16 .92 1.31 1.11 1.15	1.18 1.17 1.36 1.33 .87 1.04 1.19 .99 1.10 1.12 .84 .95 1.15 1.06 1.05 1.15 1.13 .97 1.05 1.06 1.17 1.27 1.13 1.15 1.13	1.09 1.38 1.40 1.24 .98 1.27 1.16 1.00	1.11			1.17
.11-.20	.15	.13 .19 .15 .11 .17 .14 .13 .12 .17 .15		1.32 .96	1.47 1.29 1.09 1.01	.98 1.01 1.37 .99			1.15
.21-.50	.30	.45 .21 .26 .23 .21 .35 .37 .27 .28 .39 .22 .27 .43 .28 .26 .34 .24 .30 .32	.90 1.10 1.32 1.27	1.33	1.00 1.24 1.00	1.19 1.39 .98 .92 1.00 .96	.98 .99 1.01 1.00 .98		1.07
.51-1.00	.68	.51 .65 .70 .67 .58 .94 .55 .89 .59 .60 .75		1.44		.81	1.01 .99 .91 .87 .93 1.21 .95	.87 .96	.99
1.01-2.00	1.43	1.99 1.35 1.05 1.78 1.32 1.08				1.05	.98 .97 .93 .99	.98	.98
2.01-5.00	2.95	3.8 2.2 3.6 2.3 3.1 2.3 3.4	Relative Attractiveness			1.05	.91 .93	.79	.92
>5.0	6.23	3.3 6.7 6.7				.98 .88 .72	.72	.84 .74	.81
		Occurrence Averages Relative Attractiveness	1.21	1.13	1.16	1.03	.94	.87	

The interval averages and the average occurrence values are also given.

The tables below show the interval and occurrence averages for the respective variables. Note that the "TABHL" function representing the influence of the absolute housing density is scaled to insure proper magnitude of the relative attractiveness in the model. The scaling factor is the largest value of the relative attractiveness (1.17), and all other values are standardized to this (as a base of one). In the formulation of the relative attractiveness the two influences shown below are multiplied together, and if one of them is not scaled, an ususually high relative attractiveness would occur.

Influence of Relative Housing Density on Relative Attractiveness

Internal Averages

Relative Attractiveness	1.21	(1.19)	1.16	1.03	.94	.87
Relative Housing Density	.13	.30	.50	1.22	2.91	14.60

Derived "TABHL" Function

Relative Attractiveness	1.20	1.175	1.14	1.11	1.07	1.03	1.02	1.01	1.00	.99
Relative Housing Density	.2	.4	.6	.8	1.00	1.2	1.4	1.6	1.8	2.0

Influence of Absolute Housing Density on Relative Attractiveness

Internal Averages

Relative Attractiveness	1.17	1.15	1.07	.99	.98	.92	.81
Absolute Housing Density	.05	.15	.30	.68	1.43	2.96	6.23

Derived "TABHL" Function

Scaled Relative Attractiveness	.96	.89	.85	.85	.837	.833	.83	.827	.823	.82
Relative Attractiveness	1.12	1.05	1.00	.99	.985	.9825	.98	.973	.967	.96
Absolute Housing Density	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0

As stated previously, all "TABHL" functions in the population and industrial sectors were derived in this manner. Following is a listing of the "TABHL" functions in the model, the source of data for each, and their respective interval and occurrence averages where applicable.

TABHL Constants--Listing

1) Influence on the Tax Ratio Needed--Perceived on the Tax Ratio

Source: Interview--Financial Services

Tax Ratio	.6	1	1.4	1.8	2.2	2.5	2.8	3	3.2	3.4
Tax Ratio Needed--Perceived	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0

2) Influence of the Housing Density on the Per Acre Market Value of Property

Source: 22,24,31, Interview--Tax

Influence on Per Acre Market Value	1.25	1.80	1.85	1.90	1.95	2.00	2.05	2.10	2.15	2.20	2.25	2.30
Housing Density	.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00

3) Environmental Per Capita "Other Funds"

Source: 22,24

Environmental Per Capita "Other Funds:	70	140	252	373	445	484	482	500	520	540	560
Time	0	10	20	30	40	50	60	70	80	90	100

This assumes that the percentage change from 1960 to 1970 will gradually decrease to a constant four percent growth per decade from 2000 to 2060.

4) Influence of the Debt Limit Comparison on "Other Funds"

Source: Interview--Financial Services

Influence on "Other Funds"	1.2	11.2	1.2	1.2	1.2	1.2	1.15	1.1	1.05	1
Debt Limit Comparison	-.10	-.08	-.06	-.04	-.02	0	.02	.04	.06	.08

5) Environmental Per Capita Expenses

Source: 22,24

Environmental Per Capita Expenses	169	270	400	516	578	636	700	770	847	932	1025
Time	0	10	20	30	40	50	60	70	80	90	100

This assumes that the per capita expenses' percentage increase from 1960 to 1970 gradually decreases to a constant ten percent growth per decade from 2000 to 2060.

6) Influence of the Debt Limit Comparison on Expenses

Source: Interview--Financial Services

Influence on Expenses	.65	.65	.65	.65	.65	.75	.8	.85	.9	.95	1
Debt Limit Comparison	-.10	-.08	-.06	-.04	-.02	.00	.02	.04	.06	.08	.10

7) Influence of the Environmental Yearly Percentage Change (S.M.S.A. Population) on the Actual Relative Attractiveness

Source: 22,24

Influence on Relative Attractiveness	5.85	2.94	1.97	1.48	1.23	1
Environmental % Change--Population	.005	.01	..015	.02	.025	.03

8) Environmental Yearly Percentage Change in Population

Source: 22,24

Environmental Percent Change	.03	.0275	.025	.0225	.02	.0175	.015	.0125	.01	.0075	.005
Time	0	10	20	30	40	50	60	70	80	90	100

9) Relative Attractiveness Conversion Table

Source: 22,24

Actual Relative Attractiveness	-2	-1.33	-.67	0	.67	1.33	2	2.67	3.33	4
Relative Attractiveness	.91	.93	.95	.97	.99	1.01	1.03	1.05	1.07	1.09

10) Environmental Yearly Percentage Change in Population' Influence on Relative Attractiveness

Source: 22,24

Actual Relative Attractiveness	.025	.02	.015	.01	.005	0
Yearly Percentage Change	.005	.01	.015	.02	.025	.03

11) Influence of Absolute Housing Density on the Relative Attractiveness

Source: 22,24

Interval Averages

Standardized Influence	1.00	.98	.92	.84	.83	.79	.69
Influence of Housing Density	1.17	1.15	1.07	.99	.98	.92	.81
Absolute Housing Density	.05	.15	.30	.68	1.43	2.96	6.23

"TABHL" Function

Standardized Influence	.96	.89	.85	.84	.837	.833	.83	.827	.827	.82
Housing Density	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0

12) Influence of the Percentage Vacant Land on Per Capita Housing

Source: 22,24,50,51 Interview--Comprehensive Planning

Influence on Per Capita Housing	1	.97	.95	.93	.91	.9
Percentage Vacant Land	0	.2	.4	.6	.8	1.0

13) Influence of the Relative Housing Density on the Relative Attractiveness

Source: 22,24

Interval Averages

Influence on Relative Attractiveness	1.21	(1.19)	1.16	1.03	.94	.87
Relative Housing Density	.13	.30	.50	1.22	2.80	13.2

"TABHL" Function

Influence on Relative Attractiveness	1.20	1.175	1.14	1.11	1.07	1.03	1.02	1.01	1.00
Relative Housing Density	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8

14) Environmental Housing Density

Source: 22,24

Environmental Housing Density	.28	.41	.6	.75	.92	1.1	1.3	1.47	1.61	1.73	1.82
Time	0	10	20	30	40	50	60	70	80	90	100

This varies directly with the environmental yearly percentage change in population.

15) Influence of the Relative Per Capita Income on the Relative Attractiveness

Source: 22,24

Interval Averages

Influence on Relative Attractiveness	.83	.87	.93	.98	.99	1.11	(1.11)	1.11	1.12
Relative Per Capita Income	.50	.63	.78	.86	.95	1.04	1.16	1.26	1.51

"TABHL" Function

Influence on Relative Attractiveness	.93	.93	.98	.99	1	1.1	1.105	1.11
Relative Per Capita Income	.80	.85	.90	.95	1.00	1.05	1.10	1.15

16) Influence of the Perceived Relative Attractiveness on the Change in Relative Per Capita Income

Source: 22,24

Interval Averages

Influence on Change	.98	(.99)	1.00	1.00	1.07	(Change/Decade)
Perceived Relative Attractiveness	.72	.87	.96	1.05	1.15	

"TABHL" Function

Influence on Change	.999	.9995	1	1	1	1.0034	1.0068	(Change/Year)
Perceived Relative Attractiveness	.85	.90	.95	1.00	1.05	1.10	1.15	

17) Influence of the Magnitude of the Relative Per Capita Income on the Change in Relative Per Capita Income

Source: 22,24

Interval Averages

Influence on Change	1.13	1.08	(1.00)	(1.00)	1.00	.93	.88	(Change/Decade)
Magnitude	.64	.73	.86	.95	1.04	1.17	1.28	

"TABHL" Function

Influence on Change	1	1	1	1	.998	.996	.994	(Change/Year)
Magnitude	.85	.90	.95	1.00	1.05	1.10	1.15	

18) Influence of the Number of Commercial Firms on the Total Need for Industry

Source: 22,24

Interval Averages

Standardized Influence on Total Need	4.9	2.6	1.3	(1.25)	1.2	1.0	2.5	1.3
Influence on Total Need	.266	.41	.068	.059	.064	.054	.135	.072
Number of Commercial Firms	.78	2.72	4.75	7.38	9.25	11.78	16.61	26.52

"TABHL" Function

Standardized Influence on Total Need	3.5	1.8	1.3	1.2	1.1	1.0	1.7	2.5
Number of Commercial Firms	2	4	6	8	10	12	14	16

19) Influence of the Need for Industry on the Total Need

Source: 22,24

Internal Averages

Influence on Total Need	-.134	-.072	-.025	.024	.116	.196	.184	.209
Need for Industry	-.006	-.004	-.001	0	.002	.004	.006	.008

"TABHL" Function

Influence on Total Need	-.013	-.007	-.003	.002	.011	.016	.018	.019
Need for Industry	-.006	-.004	-.002	0	.002	.004	.006	.008

20) <u>Influence of the Number of Manufacturing Firms on the Total Labor Situtation</u>

Source: 22,24

<u>Internal Averages</u>

Standardized Influence on Total Labor Situation	7.6	6.6	1.0	1.0	(1.9)	4.3
Influence on Total Labor Situation	.287	.251	.038	.938	(.074)	.165
Number of Manufacturing Firms	.08	.45	.70	1.10	1.23	1.56

<u>"TABHL" Function</u>

Standardized Influence on Total Labor Situation	7.8	5.5	1	3.9
Number of Manufacturing Firms	0	.5	1.0	1.5

21) <u>Influence of the Labor Situation on the Total Labor Situation</u>

Source: 22,24

<u>Interval Averages</u>

(Change/Decade) Influence on Total Labor Situation	-.039	.053	.094	.132	.450	.306	(.298)	(.288)	.276	.263	.222
Labor Situation	-.100	-.065	-.049	-.020	-.006	.008	.026	.047	.076	.092	.115

<u>"TABHL" Function</u>

(Change/Decade) Influence on Total Labor Situation	.0002	.005	.007	.002	.0017	.0016	.0015	.0013	.0011	.0019
Labor Situation	-.075	-.050	-.025	0	.025	.050	.075	1.000	1.05	1.05

22) <u>Influence of the Relative Per Capita Income on the Percentage of the Population Which Constitutes the Labor Force</u>

Source: 22,24

<u>Interval Averages</u>

Influence on Percentage	.374	.403	.392	.382	.364
Relative Per Capita Income	.86	.95	1.04	1.16	1.26

<u>"TABHL" Function</u>

Standardized Influence on Percentage	.98	1.02	1.06	1.04	1.03	1.01	1.00
Relative Per Capita Income	.85	.90	.95	1.00	1.05	1.10	1.15

23) Influence of Per Acre Market Value on the Yearly Change in Populated Land

Source: Interview--Tax, Comprehensive Planning

Influence on Yearly Change	1	.9	.8	.5	.2	.1
Per Acre Market Value	0	10000	20000	30000	40000	50000

24) Influence of the Percentage Vacant Land on Per Capita Land Use

Source: 50,51, Interview--Comprehensive Planning

Influence on Per Capita Land Use	.7	.75	.8	.85	.9	1
Percentage Vacant Land	0	.2	.4	.6	.8	1

25) Influence of Per Acre Market Value on the Yearly Change in Industrial Land

Source: Interview--Tax, Comprehensive Planning

Influence on Yearly Change	1	1	.9	.8	.5	.2
Per Acre Market Value	0	10000	20000	30000	40000	50000

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